Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

Berlin Jahrbuch. To reduce to either of these authorities, the variation of the declination (δd) must be multiplied into 1.02. When all terms are taken into account, the latitude is

$$\lambda = 42^\circ\ 42'\ 20'' + 16''.56 + 1''.0 + 1.02\ \delta d \pm 0''.1599,$$

from which for use,

$$\lambda = 42^\circ\ 42'\ 37''.56 \qquad \text{or,} \qquad 42^\circ : 42' : 37''.6 :$$

The value of one division of the level is $0''.972 \pm {}''.033$.

Five hundred and forty-fifth Meeting.

January 25, 1865. — STATUTE MEETING.

The PRESIDENT in the chair.

The President called the attention of the Academy to the recent decease of two of its members, — Hon. Edward Everett and Mr. W. P. G. Bartlett, of the Resident Fellows.

Professor Henry D. Rogers, of Glasgow, was elected an Associate Fellow in Class II. Section 1.

Mr. Frederick W. Putnam, of Salem, was elected a Resident Fellow in Class II. Section 3.

Five hundred and forty-sixth Meeting.

February 14, 1865. — MONTHLY MEETING.

The PRESIDENT in the chair.

The President called the attention of the Academy to the recent decease of Capt. J. M. Gilliss, an Associate Fellow, and the Director of the National Observatory at Washington.

Mr. Ferrel made the following communication: —

"It was shown in a note read on a former occasion, that if the tidal wave of the ocean is on an average two feet high and displaced two degrees by friction, the effect of the moon's attraction on the tidal wave must cause an increase of $\frac{1}{140}$ of a second in the length of the day in 2,500 years. From this we may readily determine that the earth's rotatory velocity relative to the moon is diminished, in round numbers, the $\frac{1}{280000000}$ part in a century. Now if we suppose the moon to have been originally in a fluid state, it may be demonstrated that the effect of the earth in retarding the moon's rotatory velocity would have been to that of the moon in retarding the earth's rotatory velocity, all other conditions being the same, as the square of the earth's mass is to that of the moon, or as 6,400 to unity, assuming the mass of the moon to be $\frac{1}{80}$th of that of the earth. But the density of the tidal wave on the earth is much less than the mean density of the earth, and also than the density of the earth's surface, and it moreover occupies only about three fourths of its surface, so that we may assume, if the moon be considered homogeneous or nearly so, that the effect of the earth upon the moon must have been, at least, 20,000 times greater than the effect of the moon upon the earth in diminishing the rotatory velocity. Hence, if we assume that the rotatory velocity of the moon originally was equal to that of the earth, and its tidal wave was displaced two degrees on its surface by friction, it would have lost $\frac{1}{14000}$ part of its rotatory velocity relative to the earth in a century, and consequently, if the amount of tidal displacement could have remained the same, the time of the moon's rotation on its axis would have been reduced to the time of its revolution in its orbit, as we now find it, in 14,000 centuries. But if we suppose friction to diminish with the velocity of rotation relative to the earth, the amount of tidal displacement would diminish in the same ratio, so that if we put v for the rotatory velocity of the moon relative to the earth at any time t, the original velocity being considered unity, we get from the preceding condition,

$$dt = -14{,}000 \frac{dv}{v}.$$

Putting m for the modulus of common logarithms, this gives

$$T = -\frac{14{,}000}{m} \log. v',$$

T being the time in which the original rotatory velocity would be reduced to some given velocity v'.

From the preceding equation it is seen that the rotatory velocity of the moon relative to the earth, or to the time of its revolution, could never have been reduced to nothing, however long the moon might have remained in a fluid state, but that it could have been reduced within any assigned limits, however small. Now Laplace has shown, that in order that the mean relative velocity should become nothing, or in other words, that the time of rotation should be equal to the time of revolution in the case of the solid spheroid, it is not necessary that these motions should have been exactly so at the origin of these motions, which is infinitely improbable, but only that they should have differed by a very small quantity; hence, however much these motions may have differed originally, it was only necessary that the difference should be reduced within certain very small limits by tidal action before solidification, in order that the mean motions should be made to coincide afterwards. The reason of this is readily seen if we consider that at the time of solidification, the longer axis of the spheroid would be almost exactly directed toward the earth, and that at that time, if there was still a very small velocity of rotation relative to the earth remaining, the attraction of the earth upon the excess of matter of the spheroid above that of the inscribed sphere, would bring the vertex back before it would move through a quadrant, and thus prevent a rotation and cause a libratory motion, the period of which, according to Laplace, upon the hypothesis of homogeneity, would be about seven years. But the motion would not only have to be too small to carry the vertex of the spheroid through a quadrant, but too small to carry it so far as to make the libratory motion observable from the earth; for, I believe, no such motion has been observed. If, with Laplace, we assume that the coefficient of the term expressing the libration must be 6,000 centesimal seconds, or more, in order to be observable from the earth, we can readily determine upon this hypothesis that the daily rotatory velocity of the moon, at the time of solidification, must have been reduced, at least, to $\frac{1}{300000}$ part of a revolution. Substituting this for v' in the preceding equation, we get

$$T = \frac{14{,}000}{m} \log. 300{,}000.$$

This equation gives, in round numbers, T equal to about 175,000 centuries.

We know nothing with regard to the amount of rotatory motion which the moon may have had originally, or with regard to the amount of displacement of the vertex of the spheroid or tidal wave caused by friction, and the preceding hypotheses upon which our results are based have been assumed, not because they are considered the most probable, but merely as a basis for results, from which approximate results can readily be obtained for any other hypotheses.

It is extremely improbable that the two motions should have originally corresponded with each other, so nearly as Laplace's limits require, by mere accident, but much more probable that they were made to coincide very nearly before solidification, by tidal action, which, I think, has been shown to be an adequate cause for this near coincidence. This idea, so far as I know, was first suggested in my paper, in Gould's Astronomical Journal, in the year 1853. The same was also advanced by Helmholtz, in a lecture at Königsberg, in the year 1854.

The following paper was presented: —

Proofs of the Animal Nature of the Cilio-flagellate Infusoria, as based upon Investigations of the Structure and Physiology of one of the Peridiniæ (Peridinium Cypripedium, n. sp.). By PROF. H. JAMES CLARK, A. B., B. S.

Whatever tends to elucidate the doubtful nature of any group of beings which stands undecided (as it were on the dividing line) between sentient and non-sentient things, has an importance, at the present day, which would not have been deemed worthy of very grave consideration before the theories of Spontaneous Generation, and what is sometimes mistakenly called Darwinism, had been revived. The resurgence of these doctrines has given a prominence to the discussion of the character of the lowest, obscure forms of life, simply because, in their extreme simplicity, they hardly seem to rise above a state of inorganic nature, and their vitality is exhibited in such a guise as would readily be mistaken for the operation of exo-endosmotic, inanimate, inorganic forces. Hence the readiness, the eagerness with which the Physicists of the Materialistic school clutch at these "toys" of the older microscopists, hoping therein to find an abundance of argument by which they may prove that rock and flesh do not incompatibly jostle each other whenever they come in contact.

Claiming, and justly too, that these extremes of the inorganic and organic bodies are naturally and incontestably related to each other through their common basis, the simple elements of the chemist, it does not seem possible to the Materialist that their relations should be changed, or dissevered, by the introduction of any modes of existence, however varied or elevated. The Carbon, the Hydrogen, the Nitrogen, and the Oxygen once being established as definite existences, they always remain C, H, N, and O, no matter under what forms or relations they may be disguised: the various *modes of being* not in the least changing the *fact* of their existence. For instance, they say, the transition from one kind of animate being to another kind is only a graduated change in the mode of existence, or of the manner of an outward expression of the relations of the component *elements* of the organism; certainly not an actual metamorphosis of the nature of these elements. To this assertion there may not possibly be any objection; but if the same explanation were urged for the transition to the Monad from the infinitesimally small, vibrating, inorganic corpuscle of the "Brownian motion," we have not come to that state of knowledge of the forces of nature to so readily accept it as in the former case. Still the growing tendency, among the philosophical chemists, to merge the vital and the inorganic forces into one, would seem to be inevitably preparing us to regard such a transition as identical in kind with that which obtains among the undoubtedly organized bodies, whether animals or plants.

In this state of hesitancy to step across the vanishing line of demarcation, between the animate and the inanimate, we can at least safely venture to give, in general terms, an expression of the relations of the three forms of existence. We may say that it is the *mode of existence* which constitutes the difference between the inorganic and the organic bodies, or between the two forms of organic life, viz. animals and plants. So that every fact enunciated in regard to an animal or plant is the record of a *symbol* of one of the methods of existence, or of the nature of the influences which enter into the life of the being.

From this point of view the study of these insignificants rises to the rank of the highest philosophical inquiry, and the minute wonders of the "microscopist" become the agents in the pursuit after the knowledge of the ways of the Infinite, which one could hardly have the temerity to smile at.

These thoughts have been suggested by the results of some investigations into the thus far doubtful animal nature of the Cilio-flagellate Infusoria, as the Peridiniens and their congeners are designated by Claparède in his, conjointly with Lachman, most recent publications upon the Infusoria.*

---

* Claparède and Lachman, Étude sur les Infusoires et les Rhizopodes, Mem. de l'Ins. Genevois, Tomes V., VI., VII., 1858 - 1861.

In order that the various points of the proof, that the Peridiniens are undoubtedly animals, may be comprehended in systematic sequence, it seems most desirable to present them under separate sections, each devoted to some particular vital function.

Habitat and Form. There is probably no generic difference between the species in question here and those described and figured by Allman, in the third volume of the Journal of Microscopical Science, 1856, and by Claparède in the memoir above referred to; but in their specific relations no doubt they are distinct. This (fig. 1, 2, 3) has an oblique pyriform outline, more than one third longer than its greatest breadth, and hollowed on one side by a broad longitudinal depression (*d*), extending from the narrower end (P) to a short distance beyond the broadest part of the body. Not far from the narrower end the so-called flagellum (*fl*) is attached, in the middle line of the broad depression, and is so long as to project beyond the end near to which it is situated. As the narrower end (P) is always the posterior, and the broader end (A) the anterior in the act of swimming, and the relations of the other parts of the body, such as the position of the mouth (*m*), and particularly the trend of the œsophagus (*œ*), correspond to these, the one which precedes should be called the anterior, and the other the posterior end of the body; and as such they will hereafter be designated in this article.

There are two shallow furrows which encircle the body; one (*pf*), rather broad, passes obliquely backwards and around it just behind its middle, and the other (*af*), quite narrow, encircles the broader end just in front of the termination of the broad longitudinal depression above mentioned. The whole of the body posterior to the narrower transverse furrow is clothed with vibratile cilia, but the anterior end is devoid of them, and appears to be covered by a low cap (*pc*) in the form of the segment of a sphere. In the young this cap is so shallow as to be readily overlooked, during the motions of the animal. Close to the posterior end there is a large, clear vesicle (*cv*), which is quite conspicuous, even during the rapid motions of the animal. This is the *contractile vesicle*, which will be described presently. In point of sensitiveness this Peridinium exhibits it in almost as great a degree as Pleuronema and many other timid Infusoria. These are the most evident and striking features, such as readily attract the attention when the body is in motion; and, moreover, they are the chief and characteristic traits of this species. The specific name is derived from the resemblance in the form of the body to the labellum of one of the Orchidaceæ, viz. Cypripedium. It is very common in the fresh-water ditches and slow streams about Cambridge; and in the aquarium congregates in great numbers around decaying matter. It varies from $\frac{1}{300}$ to $\frac{1}{260}$ of an inch in length, but occasionally adults were found $\frac{1}{150}$ of an inch long. It is probable, however, that the latter were in a preparatory state, just before self-division. The color is a uniform light brown, which resides mostly in the derm.

Contractile vesicle. This organ (*cv*) is so conspicuous, in the species before us at least, that one is apt to wonder why it has not been discovered before. The only reasonable excuse for this seeming delinquency would appear to be, that the animal is so incessantly active and so rapid in its motions, that a large amount of patience could hardly compensate for the want of a quiet subject. Fortunately, at the present day, our lenses, even of moderate power, are constructed with such large angles, broad fields, and excellent definition, that the difficulty of keeping the infusorian in sight, and of getting a clear, decided view of its interior, are about done away with. By strewing the glass slide with abundance of indigo, little lagoons are formed here and there, in which, when the specimens are plentiful, there is no difficulty in finding and confining any particular individual, without the necessity of a thin glass covering. In this way the motions of the body are reduced to a simple revolution on its longer axis, with an occasional inversion, end for end. The eye soon gets accustomed to the rhythmical appearance of any particular region as it comes round at each revolution, so that, by a systematic study of each and every feature, a knowledge of the whole organism may be obtained as readily as in most infusoria. The contractile vesicle is invariably situated close to the narrower, or posterior, end of the body, but at a considerable distance from the ventral, dorsal, or lateral surfaces. At the moment just before systole, it has a perfectly globular form (fig. 1, *cv*), and a very sharp, strongly refracting, conspicuous contour, and occupies rather more than the middle third of the transverse diameter of the body at this point. The systole and diastole are as regular in their recurrence as in any of the ciliated infusoria, and as conveniently observed. The systole, in perfectly fresh specimens, occurs with perfect regularity *once in forty seconds*, as numerous and carefully registered observations prove. As in other infusoria, between diastole and systole, the vesicle is more or less irregular in outline, but gradually approximating to a spherical form.

At the moment of systole it rather quickly changes from a broad spheroidal figure to one which is globular, and then contracts suddenly and rapidly until it is nearly invisible. The diastole then follows slowly, and during this it passes from a jagged, rounded outline (fig. 3, *cv*) to a lenticular form (fig. 2), then to a hemispherical shape (fig. 4) with the flattened side next to the posterior end of the body, and finally assuming a spheroidal contour it remains quiet awhile, until the time for the next systole. If the water is not renewed the specimens become unhealthy, which they exhibit by changing their form, and swelling up into an oval, and finally a globular mass. In such a condition the systole of the contractile vesicle oftentimes occurs five or six times in a minute, and will continue at that rate even when the animal is very much flattened out, and until it bursts or falls to pieces. Tincture of opium stops the action of the contractile vesicle almost immediately, even before the rest of the body is sensibly affected by it. The effect is to swell the vesicle to an enormous size, and then, breaking through the posterior end of the animal, it expands to a dimension often exceeding that of the whole body before it bursts.

The mouth (*m*). That this creature has a mouth might be premised from the manner in which particles of indigo or carmine approach and recede from the body. When the animal is moored by its flagelliform appendage (*fl*), and gyrates about it as if on a pivot, these particles of colored food may be seen to pass along the face of the broad longitudinal depression (*d*), and, striking the body just behind its mid-region, glance off in a backward direction. At the point where the indigo strikes may be seen an obliquely longitudinal, ovate opening (*m*), which leads into an elongated funnel-shaped cavity (*œ*). The former is the mouth, and the latter is the œsophagus. The mouth lies altogether within the posterior obliquely transverse furrow (*pf*), and extends from its anterior to its posterior edge, trending diagonally across the axial plane of the body, from right, backwards, toward the left. Its anterior edge (m^1) is broad, and from thence it gradually narrows to a sharp angle, which forms the posterior edge. It is so inconspicuous that in all probability it is nearly or altogether closed, except when taking in food; certainly it is not one of the prominent features of the organism, although one of the most important. When the animal is in a sickly condition, and swollen up, the mouth is easily descried, but its relations are not readily made out, because in this state the annular furrows are all obliterated; yet its connection with the œsophagus at such a time is clearly seen. There are no appendages whatever about, or belonging to the mouth; not even the flagelliform body (*fl*) has anything to do with it, but is attached to the body at a very sensible distance (*fl*^{1}) behind it. It would seem, therefore, to be dependent upon the simple cilia around it for the transfer of food to its lips. From the mouth the *œsophagus* (*œ*) passes obliquely backwards and toward the dorsal region, at least half-way through the body, and then terminates, rather abruptly, just before the contractile vesicle, but a little to the right side (fig. 3, *œ*) of the axial plane. At the mouth it is widest antero-posteriorly, but suddenly narrowing a little, it afterwards gradually lessens its calibre as it extends into the body, and finally ends as just described. The whole track of this channel is much more readily seen than the mouth. The food is taken in such excessively small particles that its entrance into the mouth cannot be detected with any degree of satisfaction; and a single digestive vacuole (*dv*) requires from twenty minutes to half an hour to form and fill; and although it may be comparatively quite large, even two thirds of its fullest capacity, yet so infinitesimally minute are the particles that even indigo or carmine is not readily seen, although it may be the only kind of food present. Beyond this point, however, these coloring matters become rapidly visible, so that when a vacuole is fully formed, the indigo or carmine is as conspicuous as in any other infusorian. These vacuoles are very large, in fact equalling in size the contractile vesicle; and as they form sometimes pretty far back, they are apt to obscure the latter; without doubt thus causing this vesicle to be mistaken for one of them, since they bear a certain resemblance to it. No anus was detected during these investigations, although the specimens at times were kept well fed.

The locomotive organs. The most prominent among the cilia is the so-called flagellum (*fl*). This, however, is not a single filament, as has usually been asserted, but owing to the manner in which it is used it very naturally appears to be so. Most frequently its compound nature becomes apparent when the numerous cilia of which it is composed divide into two groups (fig. 7, *fl* *fl*^{1}), thus simulating a double flagellum.* At other times, after having divided into two groups, they twist about each other in such a way as to resemble a sharply-pointed screw, with a long drawn out double thread. Such is the condition in which this pseudo-flagellum is most frequently seen, and then, with the best magnifying powers, up to five hundred diameters, its compound nature is not easily recognized. But there are times when the whole group of cilia spreads out into a distinct brush, so that each individual cilium may be seen. The base (*fl*[1]) of attachment is in the axial plane of the body, a short distance posterior to the mouth (*m*), and distinctly disconnected from it, as has been already noticed. When not in motion, which seldom occurs, the brush lies along the median furrow (*mf*) which trends from the mouth to the posterior end of the animal, and in this position it projects for nearly half its length beyond the body. Its most ostensible use would seem to be that of a sort of rudder when the creature is swimming, and as a means of attachment when not progressing. The body may be seen gyrating, and at the same time revolving on its longitudinal axis, for long periods around a point to which the pseudo-flagellum is attached, and upon which it turns like a pivot. It is most frequent that, during this act, a part of the brush separates from the rest, and performs the office of an extra propeller. When the animal is darting and spinning through the water, this appendage projects obliquely from its point of attachment (as in fig. 1), and always following, with the narrower end of the body, in the rear, it seems pretty evidently to be the main agent in the various and sudden tackings to which this infusorian is addicted, and also the axis upon which the body revolves; at least the latter whirls, repeatedly changing as quick as thought from right to left, or *vice versa*, upon an imaginary axis which is oblique to its greatest length, and which exactly corresponds to the trend of the flagelliform appendage when operating in this capacity. Under these conditions the animal shoots along with a compound motion, which might be described as wabbling, or like the action of an eccentric wheel. Apparently in confirmation of this view the annular, obliquely transverse anterior (*af*) and posterior (*pf*) furrows trend almost exactly at right angles to this imaginary axis. These two furrows seem, at first sight, to be bands of *vibrating cilia*, and in fact it is in the line of their trend that these cilia are most readily detected, simply because they are rather more crowded along their edges than elsewhere; but an attentive examination reveals their presence all over the body, posterior to the anterior transverse furrow. Between the two furrows (i. e. from *af* to

---

* Claparède, *loc. cit.*, speaks of frequently noticing that some of the Ceratiums, &c. appeared to have a double flagellum. Probably they were a group of cilia divided as here described.

pf) they are longer than at the narrower end of the body, and at both points they have a pretty uniform length, moderate extension, and are very delicate, so as not to be easily observed when the body is in motion. At the anterior transverse furrow they appear to be a little longer than elsewhere, and acting more or less in concert, they have the semblance of a wreath disposed along the edge of the low skullcap-like covering (*pc*) of the anterior end.

The cuirass (*pc*). It is pretty evident that, in the species before us, this is a mere dermal specialization, without any trace of indurated matter which would entitle it to the name of a genuine cuirass. Where vibratile cilia are present no such covering can be said to exist, and as the broad anterior end (A) of the body is devoid of them, its skullcap covering is the only portion of the derm where one could expect to find a cuirass. But this it is only in form, since it participates with the rest of the body in the general expansion when an individual is dying. It has, without doubt, a different character from the rest of the skin, for the style of ornamentation is not of the same kind, and, curiously enough too, it is less truly ornamented than in the other regions of the body, amounting to a mere scattered punctuation; whereas over the field where the cilia prevail, these punctuations, which are in reality minute, cylindrical, strongly refracting bodies, standing perpendicular to the surface of the derm, are arranged in perfectly regular rows, which have a different character in the three regions posterior to the pseudo-cuirass. In the space (fig. 5, D) between the anterior (*af*) and posterior (*pf*) transverse furrows, the rows trend longitudinally and transversely; in the posterior transverse furrow (*pf*) they have the same arrangement as the last, but they are more closely set together; and in the region behind the latter furrow they trend in decussating lines (P), like those in the carapace of Arcella vulgaris.

This region is also characterized by being divided longitudinally, on the ventral side, by a furrow (fig. 1, 2, 6, *mf*) which trends in a direct line from the end of the body to the mouth, and gradually widens anteriorly where it joins the annular, transverse furrow (*pf*). At this point of juncture the flagellar appendage arises, and opposite to it the anterior edge of the transverse furrow just mentioned forms an inequilateral angle at the broader margin (m^1) of the mouth, so that the right and left halves of this furrow are rendered asymmetrical; a character in perfect accordance with that of many, if not of all the Peridiniæ.

The nucleus (*n*) at the period when these observations were made,

Fig. 1.

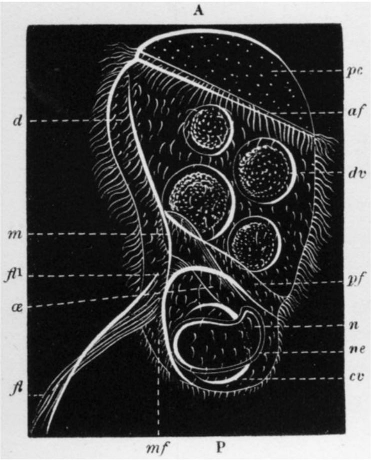


Fig. 2.

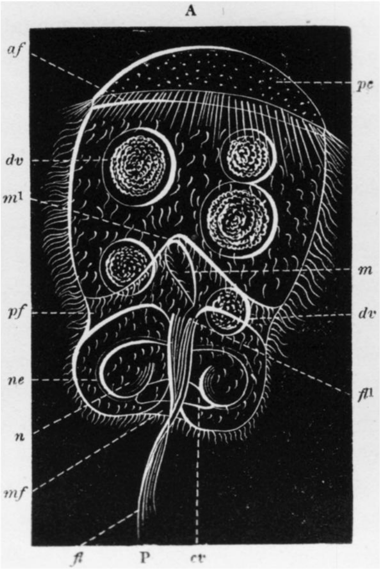


Fig. 3.

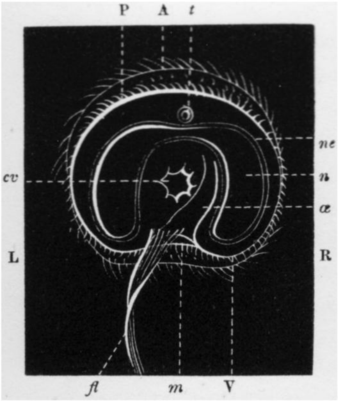


Fig. 4.

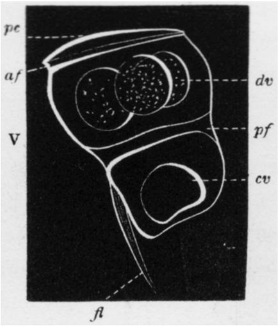


Fig. 5.

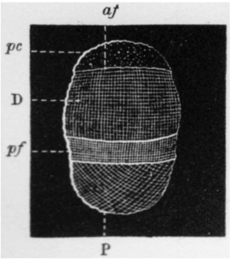


Fig. 7.

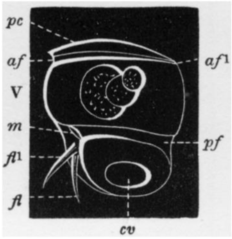
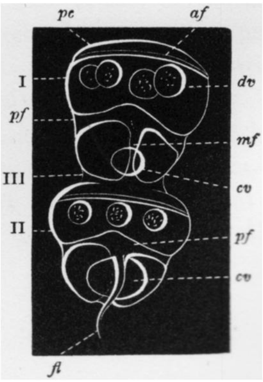


Fig. 6.



[To face page 401.]

viz. early last December, the genital organ invariably laid transverse to the longitudinal axis, and occupied a very large portion of the bulk of the posterior end of the body. Most frequently it had a U-shaped form (fig. 3, *n*), and embraced the contractile vesicle with its two limbs. It was then of a yellowish brown color and perfectly homogeneous. Occasionally it was observed to be divided into three or four masses, which extended toward the region encompassed by the posterior annular furrow. While in the U-shaped form the whole semi-opaque mass was enclosed in a transparent envelope (*ne*). Oftentimes there was to be seen immediately over and close to the dorsal region of the nucleus and directly in the plane of the axis of the body, a minute, clear, vesicular corpuscle (fig. 3, *t*), which seemed to have the character of a "nucleolus" or — as is now becoming the belief, since the investigations of Balbiani and Claparède — a *testicle.*

Reproduction from the egg has not been observed, but transverse division occurred in a number of instances. In the latter case it agrees, in the process, with what Allman, *loc. cit.*, has described, excepting that the resultants (fig. 6, I., II.; fig. 7) are quite different in their proportions from the adults (fig. 1, 2, 3). At the moment of separation the young offshoot (fig. 7) is about two thirds the size of the adult, and is almost as broad as long, and bulges strongly on the ventral side (V), in front of the mouth (*m*). It has a very flat anterior end, and the pseudo-cuirass (*pc*) of this part is represented by an inconspicuous unguiform body. The anterior transverse furrow, on account of its narrowness, hardly attracts attention, except along its ventral edge (*af*), where it is rendered conspicuous by the strong projection of the unguiform cuirass. As in the adult, it is broadest ventrally, but, growing shallower, thins out (af^1), going dorsally, to almost nothing. The relations and structure of the various organs, cilia, &c. are the same as in the full-grown individuals; but with progressing growth the proportions of the diverse regions of the body change insensibly, as may be seen by comparing figures 7, 4, and 1, which are respectively representatives of the youngest, middle-aged, and adult individuals.

Description of Figures.

In all the figures the same letters refer to corresponding parts.

A. The anterior end of the body. P. The posterior end.
D. The dorsal side. V. The ventral side. R. The right side.
L. The left side.

af. anterior transverse, or annular furrow. af^1. dorsal part of *af.*

pf. posterior transverse, or annular furrow.

mf. median, or longitudinal furrow.

d. depression on the ventral side.

cv. contractile vesicle.

m. mouth. m^1. anterior edge of *m.*

œ. œsophagus.

dv. digestive vacuoles.

fl. pseudo-flagellum. fl^1. base of *fl.*

n. nucleus, or generative organ. *ne.* envelope of *n.* This is the reproductive organ, properly speaking, and *n* is the contents, or reproductive material, the future eggs.

t. nucleolus, or testes.

pc. pseudo-cuirass.

I., II. The two products of self-division. III. The annular constriction which finally separates I. and II.

Figs. 1 to 7. Peridinium Cypripedium, n. sp.

Fig. 1. Profile of an adult, seen from the left side. Mag. 500 diam.

Fig. 2. View of the ventral side of an adult. Mag. 500 diam.

Fig. 3. Posterior view of an adult; the anterior end in the distance. Mag. 500 diam.

Fig. 4. A young individual. Mag. 300 diam.

Fig. 5. An adult gradually dried up. Dorsal view, to show the arrangement of the punctiform ornamentation of the derm. 500 diam.

Fig. 6. The process of self-division, just half an hour before separation. Ventral view. 200 diam.

Fig. 7. Profile of I. fig. 6, just at the moment of separation. 200 diam.

The following memoir by Mr. Francis was presented by Professor Treadwell with these introductory remarks: —

About five years ago I called the attention of the Academy to the subject of the strength of cast-iron columns, and presented a paper, which was printed in the Proceedings, containing a short examination of the state of our knowledge upon that subject. It was then thought desirable that a more elaborate examination should be given to it; and a committee was appointed for the purpose. This committee, after two or three consultations, gave over all attention to it, and there the matter has rested, so far as the committee, as a body, were concerned, to this day. One of their members, however, Mr. J. B. Francis of Lowell, whose professional engagements gave him a particular interest in the investigation, finding that nothing would be done by the committee collectively, took up the subject in his own way, and has pursued it at his leisure up to the present time. He has made a most thorough examination of all the experiments that have been published, or that came within his reach, with the conclusions which have been drawn from them, together with the formulas and rules that have been proposed for practical constructions. Proceeding thus, he has, after a careful and patient examination of the experiments and the reasoning of the several investigations, selected such of the conclusions and formulas as have appeared to him quite trustworthy, and from combining, and, in some cases, modifying these, he has calculated a most elaborate set of tables, by which the architect or practical workman can find a column suited to any structure, and which may be relied upon as safe for all purposes, ordinary, or even extraordinary. I consider the paper thus produced by Mr. Francis as of great value, and believe that it will become a work of the first authority, and of constant reference for the builder.

This paper might, most properly, have been presented to the Academy by Mr. Francis himself, and I think ought to have been thus presented, without my intervention. He has, however, (probably from my having formerly called the attention of the Academy to the subject, and having been chairman of the committee before referred to,) requested me to present the paper for him. I consider myself honored in being thus called upon to communicate a work of such merit to the Academy. Let it be understood, however, that I do not present it as chairman of the committee formerly appointed to examine the subject (this committee have really produced nothing from their charge), but as the sole and private work of Mr. Francis, who alone is entitled to the thanks of the Academy and the community for his most laborious and useful work.

On the Strength of Cast-iron Pillars, with Tables, for the Use of Engineers, Architects, and Builders. By JAMES B. FRANCIS, *Civil Engineer.*

Until the year 1840 the only rule in common use for computing the strength of cast-iron pillars was that given by Tredgold, in his essay on the strength of cast-iron and other metals.* This rule was not founded on experiments made on pillars, or on sound theoretical principles; fortunately, however, in its application to cases where great weights were to be supported, the errors were on the safe side. Profound theoretical investigations have been made by Euler and others on the resistance of pillars to *incipient flexure;* the results are valuable, but are not directly available for the wants of practice.

---

* Practical Essay on the Strength of Cast-iron and other Metals. By Thomas Tredgold, London, 1822, and three subsequent editions.

In the year 1840, Mr. Hodgkinson of Manchester, England, presented to the Royal Society his first paper on the strength of cast-iron pillars.* It contains an account of an elaborate series of experiments, on a large scale, made at the expense of William Fairbairn of Manchester, and affording ample data for determining the formulas for computing the breaking weights of solid and hollow cylindrical pillars of cast-iron, and of ordinary dimensions. The formula determined by Hodgkinson from these experiments for hollow cylindrical cast-iron pillars, the lengths being not less than thirty times the external diameters, and the ends being flat, that is to say, with the ends finished in planes perpendicular to the axis, the weight being uniformly distributed on these planes, is

$$W = 99{,}318 \frac{D^{3.55} - d^{3.55}}{l^{1.7}}, \qquad (1)$$

in which

W = the breaking weight, in pounds.
D = the external diameter, in inches.
d = the internal diameter, in inches.
l = the length in feet.

When the pillars were shorter than thirty external diameters, it was found that they would break with less weight than is given by formula (1). In a long pillar the pressure tends to break it by crushing as well as by flexure, but it fails from flexure with a weight which is too small to sensibly affect it by crushing alone. In a short pillar, on the other hand, the weight required to break it by flexure is so great that the crushing effect becomes sensible, and it fails from the joint effects of the force. It was found by experiment that the effect of the crushing force became sensible when the pillars with flat ends were shorter than thirty times the external diameter, and the formula given by Hodgkinson for the breaking weight of such pillars is

---

* Experimental Researches on the Strength of Pillars of Cast-iron and other Materials. By Eaton Hodgkinson. Philosophical Transactions of the Royal Society of London, for 1840. Part II.

$$W' = \frac{Wc}{W + \frac{3}{4}c}; \qquad (A)$$

in which

W = the breaking weight by formula (1).

W' = the breaking weight for the combined effects of flexure and crushing.

c = the weight which would crush the pillar without flexure, which Hodgkinson finds for Low Moor iron, No. 3, is 109,801 pounds per square inch of section; consequently,

$$c = 109{,}801 \times \tfrac{1}{4}\pi (D^2 - d^2).$$

Substituting the value of c in (A), and reducing, we have

$$W' = \frac{86238\,(D^2 - d^2)\,W}{W + 64678\,(D^2 - d^2)}.^{*} \qquad (2)$$

---

* In computing the breaking weights of a series of pillars, in order to preserve continuity in the results obtained by formulas (1) and (2), it is necessary at the point where one formula is substituted for the other that we should have

$$W = W';$$

consequently, at this point

$$86238\,(D^2 - d^2) = W + 64678\,(D^2 - d^2).$$

Substituting the value of W in (1), and reducing, we have

$$l = 2.456\left(\frac{D^{3.55} - d^{3.55}}{D^2 - d^2}\right)^{\frac{1}{1.7}}$$

For simplicity, confining ourselves to solid pillars, in which $d = 0$, we have, by substituting this value in the last equation,

$$l = 2.456\,D^{0.91}$$

l, in this formula, is the length, in feet, of a solid pillar of the diameter D, in inches, for which formulas (1) and (2) give the same breaking weight.

When $D = 0.1$ $\therefore l = 0.3022$ feet $= 3.6264$ inches $= 36.264$ diameters.
" $D = 0.821$ $\therefore l = 2.0525$ " $= 24.6300$ " $= 30.000$ "
" $D = 5.0$ $\therefore l = 10.6240$ " $= 127.4880$ " $= 25.498$ "
" $D = 10.0$ $\therefore l = 19.9630$ " $= 239.5560$ " $= 23.956$ "

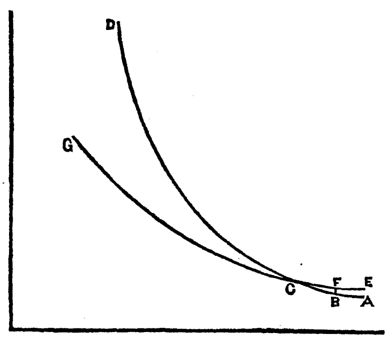
The substitution of formula (2) for formula (1), for pillars of lengths less than 30 diameters, is for the purpose of diminishing the computed breaking weights to conform to the diminished strength of such pillars, on account of the crushing effects of the weights; but in all solid pillars of more than 0.821 inch in diameter there are certain lengths in which the substitution of formula (2) for (1) has the contrary effect; thus, in a pillar 5 inches in diameter, for all lengths between 25.498 diameters and 30 diameters, the breaking weights computed by formula (2) exceed those

Numerous experiments were also made on pillars with the ends rounded, so that the weights bore on the axis. Most of these experiments were made on solid pillars; the hollow ones had hemispherical caps fitted on the ends. It was found that their breaking weight was about one third that of pillars of the same dimensions with flat ends. Some experiments were made on pillars with one end flat and the other end rounded; their breaking weight was about two thirds that of pillars of the same dimensions with both ends flat.

Hodgkinson determined separate formulas for the breaking weights of both solid and hollow cast-iron pillars, with flat ends and also with rounded ends; for practical purposes, however, formulas (1) and (2) are sufficient, recollecting that in a solid pillar $d = 0$, and that the breaking weight of a pillar with rounded ends is one third of that given by formulas (1) and (2). The breaking weight of pillars with rounded ends is so much less than that of pillars with flat ends, that Hodgkinson did not find the crushing effect sensible in pillars with rounded ends when longer than fifteen external diameters; consequently, one third the value of W', as given by formula (2), will be less than the true breaking weight, when the formula is applied to pillars with rounded ends of lengths between fifteen and thirty diameters. For simplicity, however, I propose to adopt thirty diameters as the limit between formulas (1) and (2), whether the ends are flat or rounded. The errors resulting will be on the side of security, and in ordinary cases, not being large, may be neglected. In a solid pillar with rounded ends, 10 feet long and 8 inches in diameter, the computed breaking weight is about one fourth too small.

---

computed by formula (1), the maximum excess being about 6 per cent. This is illustrated by the diagram in the margin. The curve A B C D represents the breaking weights of solid pillars, 5 inches in diameter, by formula (1), and the curve E F C G the same by formula (2), the abscissas being the lengths in diameters, and the ordinates the breaking weights. The curves intersect at the point C, the abscissa of which is 25.498. According to Hodgkinson the breaking weights are represented by A B F C G, the abscissa of the points B and F being 30.



Two experiments were made by Hodgkinson on pillars with the pressure applied at intermediate points, between the centre and circumference. When the pressure was applied parallel to the axis, and half-way between the axis and one side, the breaking weight was about 54 per cent of the breaking weight of a pillar of the same dimensions with the ends rounded, so that the pressure was applied at the axis. In another experiment, the pressure was applied at one eighth of the diameter from one side; in this case, the breaking weight was about 61 per cent of that of a pillar of the same dimensions with rounded ends. In two experiments the pressure was applied in the direction of a diagonal; in both cases the breaking weight was nearly the same as for pillars of the same dimensions with rounded ends. A few experiments were also made on pillars with rounded ends, and other forms than cylindrical. Square pillars had an average breaking weight about 58 per cent greater than cylindrical pillars of diameters equal to the sides of the squares. The square pillars generally failed in the direction of the diagonals. A pillar of the section ✚, 90.75 inches long, 3 inches across, and the ribs 0.48 inch thick, had a breaking weight 63 per cent greater than the computed breaking weight of a solid cylindrical pillar of the same weight and length. A hollow cylindrical pillar of the same weight and length, and of an external diameter equal to the width of the ✚, has a computed breaking weight about double that found by experiment for the form ✚. A pillar of the section H, 3 inches in height and 2.5 inches in width, of the same length and nearly the same sectional area as the preceding, had a breaking weight about 2.6 times the computed breaking weight of a solid cylindrical pillar of the same weight and length. A hollow pillar, 3 inches in external diameter, and of the same weight and length, has a computed breaking weight about 19 per cent greater than was found by experiment for the pillar of H section.

Several pillars, larger in the middle than at the ends, were tested for the purpose of determining the most economical form; the experiments were not sufficiently numerous or varied to permit any definite conclusions to be drawn. It would appear, however, that in pillars with rounded ends there is a distinct advantage in making them somewhat larger in the middle than at the ends; that is to say, a pillar may be made of this form which would have a breaking weight greater than a cylindrical pillar of the same weight. In pillars with flat ends there is less advantage in departing from the cylindrical form. Hodgkinson observed that pillars with rounded ends generally broke at the middle only; pillars with flat ends generally broke in three places, at the middle and near each end.

In 1856, Hodgkinson presented a second paper, on the strength of cast-iron pillars, to the Royal Society.* Its special subject is the strength of pillars cast from iron from various parts of Great Britain. The experiments were made at University College, London, with a larger and more powerful apparatus than that which he previously used at Manchester. The pillars tested were longer and larger, and the results reported afford the means of testing, in a very satisfactory manner, the formulas previously determined. The earlier experiments were undertaken for the purpose of determining the laws according to which the breaking weights of pillars depended upon their dimensions. For this purpose, it was necessary to adhere to one description of iron. A Yorkshire iron, Low Moor, No. 3, was selected, which is described as a good iron, not very hard. The formulas were satisfactorily determined for this iron, but there was some risk in applying them to pillars cast from other descriptions of iron, without further experiments. In the second paper, experiments are described on pillars cast from thirteen kinds of iron, — two of them being mixtures.

For the purpose of effecting a systematic comparison between the breaking weights by the experiments of 1856 and the breaking weights computed by the formulas of 1840, the three following tables have been computed, the data being extracted from Hodgkinson's paper of 1856.

TABLE I.

Designation of the Experiments in Hodgkinson's Tables.	Description of the iron from which the pillars were cast.	External diameter.	Internal diameter.	Length.	Breaking weight by formula (1).	Breaking weight by experiment.	Proportional difference.
		In.	In.	Ft.	Lbs.	Lbs.	
Tab. I. Exp. 1	Low Moor, No. 2	2.513	1.941	10.00	31,334	34,804	+0.1107
" " 2	" "	2.520	1.903	10.00	33,268	39,166	+0.1773
" " 3	" "	3.021	2.354	10.00	58,966	66,259	+0.1237
" " 4	" "	3.035	2.354	10.00	60,627	69,932	+0.1535
" " 5	" "	3.532	2.659	10.00	110,990	110,649	—0.0031
" " 6	" "	3.555	2.693	10.00	112,122	114,479	+0.0210
" " 7	" "	3.804	3.170	9.75	113,149	112,127	—0.0090
Mean proportional difference							+0.0820

---

* Experimental Researches on the Strength of Pillars of Cast-iron, from various Parts of the Kingdom. By Eaton Hodgkinson. Philosophical Transactions of the Royal Society of London for 1857. Part III.

Table I. gives the dimensions and the breaking weights by formula (1) and by experiment of several long, hollow pillars with flat ends, made of Low Moor iron, No. 2. It will be seen that the breaking weights by experiment vary from about eighteen per cent greater to about one per cent less than the computed breaking weights, the mean being about eight per cent greater.

Table II. gives the dimensions and breaking weights of solid pillars with flat ends, cast from several kinds of iron made in Great Britain; also the breaking weights of the same pillars, computed by formula (1). It will be observed that the breaking weights by experiment vary from about thirty per cent greater to about fifteen per cent less than the breaking weights computed by the formula, the mean being about nine per cent greater.

TABLE II.

Designation of the Experiments in Hodgkinson's Tables.	Description of the iron from which the pillars were cast.	Diameter.	Length.	Breaking weight by formula (1).	Breaking weight by experiment.	Proportional difference.
		In.	Ft.	Lbs.	Lbs.	
Tab. II. Ex. 11	Low Moor, No. 2	2.553	10.00	55,215	55,973	+0.0137
" " 12	" "	2.539	10.00	54,148	55,973	+0.0337
" " 13	Blaenavon, No. 3	2.556	10.00	55,446	56,914	+0.0265
" " 14	" "	2.546	10.00	54,680	57,855	+0.0581
Tab. III. Ex. 1	Old Park, No. 1	2.503	10.00	51,471	66,792	+0.2977
" " 2	" "	2.526	10.00	53,170	65,381	+0.2297
" " 3	Derwent, No. 1	2.529	10.00	53,394	57,855	+0.0835
" " 4	" "	2.517	10.00	52,500	66,733	+0.2711
" " 5	Portland, No. 1	2.493	10.00	50,745	59,736	+0.1772
" " 6	" "	2.527	10.00	53,245	62,559	+0.1749
" " 7	Calder, No. 1	2.490	10.00	50,528	60,677	+0.2009
" " 8	" "	2.519	10.00	52,649	60,677	+0.1525
" " 9	1st London Mixture, $\frac{1}{2}$ old iron	2.533	10.00	53,695	54,562	+0.0161
" " 10	" "	2.548	10.00	54,832	59,266	+0.0809
" " 11	Level, No. 1	2.518	10.00	52,575	54,091	+0.0288
" " 12	" "	2.501	10.00	51,325	56,443	+0.0997
" " 13	Coltness, No. 1	2.516	10.00	52,426	56,443	+0.0766
" " 14	" "	2.496	10.00	50,962	48,917	—0.0401
" " 15	Carron, No. 1	2.506	10.00	51,691	52,210	+0.0100
" " 16	" "	2.510	10.00	51,984	53,151	+0.0224
" " 17	Blaenavon, No. 1	2.487	10.00	50,313	48,917	—0.0277
" " 18	" "	2.499	10.00	51,180	49,858	—0.0258
" " 19	Old Hill, No 1	2.520	10.00	52,723	44,683	—0.1525
" " 20	" "	2.523	10.00	52,946	45,154	—0.1472
" " 21	2d London Mixture, $\frac{2}{3}$ old iron	2.511	10.00	52,058	63,499	+0.2198
" " 22	" "	2.496	10.00	50,962	58,325	+0.1445
" " 23	" "	1.530	10.00	8,968	11,204	+0.2493
" " 24	" "	1.541	10.00	9,199	10,868	+0.1814
					Mean proportional difference	+0.0877

Table III. gives the results of experiments on solid pillars, cut out of the fragments of the pillars, 10 feet long, used in previous experiments, the results of which are given in Tables I. and II. In the last six experiments in Table III. the pillars were cut out of the fragments formed in the preceding experiments in the same table. The ends of all of them were turned flat and perpendicular to the axis. It will be seen that the breaking weights by experiment vary from about thirty-three per cent greater to about twenty-three per cent less than the breaking weights computed by formulas (1) and (2), the mean being about five per cent greater.

TABLE III.

Designation of the Experiments in Hodgkinson's Tables.	Description of the iron from which the pillars were cast.	Diameter.	Length.	Breaking weight by formula (1) or (2).	Breaking weight by experiment.	Proportional difference.
		In.	Ft.	Lbs.	Lbs.	
Tab. IV. Ex. 1	Old Park, No. 1	2.526	7.50	86,709	100,191	+0.1555
“ “ 2	“ “	2.503	7.50	83,938	95,487	+0.1376
“ “ 3	Derwent, No. 1	2.517	7.50	85,617	105,365	+0.2307
“ “ 4	Portland, No. 1	2.527	7.50	86,830	102,543	+0.1810
“ “ 5	Calder, No. 1	2.490	7.50	82,401	93,135	+0.1303
“ “ 6	1st Lond. Mixture, ½ old iron	2.548	7.50	89,419	93,605	+0.0468
“ “ 7	Level, No. 1	2.501	7.50	83,700	98,309	+0.1745
“ “ 8	Coltness, No. 1	2.516	7.50	85,496	87,019	+0.0178
“ “ 9	Carron, No. 1	2.506	7.50	84,296	72,437	—0.1407
“ “ 10	Blaenavon, No. 1	2.500	7.50	83,582	71,967	—0.1390
“ “ 11	Low Moor, No. 2	2.539	7.50	88,303	89,371	+0.0121
“ “ 12	Blaenavon, No. 3	2.556	7.50	90,420	85,608	—0.0532
Tab. V. Ex. 1	Derwent, No. 1	2.529	6.25	122,990	112,438	—0.0858
“ “ 2	1st Lond. Mixture, ½ old iron	2.533	6.25	123,615	114,320	—0.0752
“ “ 3	Level, No. 1	2.518	6.25	121,284	131,275	+0.0824
“ “ 4	Old Hill, No. 1	2.523	6.25	122,058	93,622	—0.2330
“ “ 5	2d Lond. Mixture, ⅔ old iron	2.511	6.25	120,206	127,432	+0.0601
“ “ 6	“ “	2.496	6.25	113,305	116,672	+0.0297
“ “ 7	“ “	1.530	6.25	19,938	26,527	+0.3305
“ “ 8	“ “	1.530	6.25	19,938	24,763	+0.2420
“ “ 9	“ “	1.541	6.25	20,452	25,939	+0.2683
“ “ 10	“ “	1.528	3.00	63,218	57,384	—0.0923
“ “ 11	“ “	1.544	3.00	65,266	70,555	+0.0810
“ “ 12	“ “	1.527	3.00	63,091	57,856	—0.0830
“ “ 13	“ “	1.531	2.50	77,812	85,138	+0.0941
“ “ 14	“ “	1.530	2.50	77,662	72,907	—0.0612
“ “ 15	“ “	1.515	2.50	75,433	70,555	—0.0647
Mean proportional difference						+0.0462

In his second paper, Hodgkinson also describes a few experiments on square pillars and on pillars with the section of an equilateral triangle; these were compared with cylindrical pillars; two of each pattern were tested, all being cast from the same kind of iron, and were of the same length and nearly the same weights. The relative strengths, reduced to the same weights, were as follows: —

Cylindrical pillar,	100.
Square “	93.
Triangular “	110.

In many of the hollow pillars tested, Hodgkinson found that at the place of fracture the metal was much thicker on one side than on the other; it would be reasonable to expect that this would weaken them sensibly, but such was not generally the case. Thus, in the third experiment in Table I., the thickness on one side was 0.55 inch, and on the opposite side, 0.17 inch. In the fourth experiment in the same table, the relative thickness on opposite sides was as 2 to 1, nearly. In both of these experiments the breaking weights were above the mean. In the third experiment the direction of the flexure was such that the convex side coincided with the greatest thickness of metal; in the other experiment the convex side coincided with the least thickness. In most cases, however, the convex side coincided with the greatest thickness.

In experiment 1, Table IX., in Hodgkinson's paper of 1840, the pillar was 7 feet $4\frac{3}{4}$ inches long, external diameter 1.78 inch, internal diameter 1.21 inch, the ends flat and well fitted. The ratio of the thickness on opposite sides of the ring of metal, at the place of fracture, was as 5 to 1. The convexity was on the thickest side. The breaking weight by experiment was 17,840 pounds, which is only about $\frac{1}{15}$ less than the breaking weight computed by formula (1).

The explanation of these remarkable results appears to me to be this: The weight being applied equally on all sides of the pillar, which is supposed to be straight when unloaded, the side having the least metal will be the most compressed; this will determine the direction of the flexure, so that its convexity will be on the thickest side. When the load is near the breaking weight, the convex side, near the middle, is subject to a tensile force, and the concave side to a crushing force. Hodgkinson found that it required seven or eight times the force per square inch to crush the kind of iron he used that it did to rupture it by a tensile force, and although the sum of the crushing forces, acting on one portion of the horizontal section at the place of fracture, largely exceeds the sum of the tensile forces acting on the other portion of the same section, the difference in the powers of the metal to resist the two forces is so great that, in a long pillar, a much less area of section is required to resist the sum of the crushing forces than to resist the sum of the tensile forces. If the iron from being harder on the thin side is less compressible on that side, or if the weight is not equally distributed on all sides, or if the pillar is not straight when unloaded, the direction of the flexure, when loaded, may be such that the convexity is on the thin side; in this case the deflection caused by the load will depend on the compression of the thick side; from the greater area subject to compression the amount of the compression, and consequently of the deflection, will be less than if the sides are of equal thickness. In either case, when the inequality in the thickness on opposite sides is not too much, the pillar may support a load as great, or even greater, than if the thickness was equal on all sides.

Hodgkinson determined a new formula for the breaking weight of hollow cylindrical pillars cast from Low Moor iron, No. 2, from the experiments given in his second paper, viz.: —

$$W = 94859 \, \frac{D^{3.5} - d^{3.5}}{l^{1.63}}. \qquad (3)$$

Formula (1) was determined from the experiments given in the first paper, which, from their wider range of dimensions, are much better fitted for such an induction than the experiments given in the second paper.

Table IV. contains a comparison between the breaking weights by experiment and by formulas (1) and (3). The pillars were all cast from Low Moor iron, No. 2, and are the same as those given in Table I. It will be seen that the computed breaking weights by formula (3) agree best with the breaking weights by experiment in the smaller pillars, and the computed breaking weights by formula (1) agree best with experiment in the larger pillars. On the whole there appears to be no doubt that formula (1) is the best determined and the safest to adopt in practice.

TABLE IV.

Designation of the Experiments in Hodgkinson's Tables.	External diameter.	Internal diameter.	Length.	Breaking weight by experiment.	Breaking weight by formula (1).	Breaking weight by formula (3).
	In.	In.	Ft.	Lbs.	Lbs.	Lbs.
Tab. I. Exp. 1	2.513	1.941	10.00	34,804	31,334	33,289
" " 2	2.520	1.903	10.00	39,166	33,268	35,350
" " 3	3.021	2.354	10.00	66,259	58,966	62,059
" " 4	3.035	2.354	10.00	69,932	60,627	63,798
" " 5	3.532	2.659	10.00	110,649	110,990	115,971
" " 6	3.555	2.693	10.00	114,479	112,122	117,103
" " 7	3.804	3.170	9.75	112,127	113,149	117,362

In applying the formulas to practice, it is of the greatest importance to determine the proper allowance to be made for possible defects, and to insure complete security against fracture, using no more material than is necessary. In doing this, many things should be considered.

The experiments from which the formulas are deduced were made on pillars of smaller dimensions than those commonly used, and they were very carefully cast from Low Moor iron, No. 3. The strength of iron in small castings is usually greater than in large castings. Low Moor iron has a very high reputation; its transverse strength, however, by Hodgkinson's experiments, appears to be less than that of many other kinds of iron. The different qualities of iron are usually classed as Nos. 1, 2, and 3, differing from each other in the appearance and properties of the material. No. 1 includes the softest and richest irons, those having the largest crystals, and containing generally the most carbon; No. 3, the hardest and densest irons, those having the smallest crystals; No. 2 irons are intermediate between Nos. 1 and 3. No. 3 iron, although the least valuable, is usually the strongest. Castings made from a mixture containing a considerable portion of old metal have usually greater strength than castings from a simple iron (see Table II.) The cheapest irons thus appear to be the most suitable for making pillars.

The experimental pillars, from which the formulas are deduced, were cast in dry sand moulds, and most of them vertically, in order to obtain, as far as possible, uniformity in the texture of the iron. This is generally understood to be the best, as it is the most expensive mode of moulding; but casting vertically does not appear to produce the strongest castings. In the experiments made in 1856 at the Royal Gun Factories at Woolwich, England, on the strength of cast-iron,* fifty-three different kinds of iron were tested; bars were cast 22 inches long, and 2 inches square; in one half of them the moulds were laid horizontally, in the other half vertically; in nearly all cases the bars cast horizontally, when subjected to a transverse strain, had a greater breaking weight than those cast vertically; the average being about 19.5 per cent greater. Founders prefer to cast pillars in moulds laid horizontally, or nearly so, on account of economy; there is, however, much greater liability to imperfections in the castings than when cast vertically.

In the experimental pillars great care appears to have been taken to make them straight; a small variation from a straight line in the axis of a pillar will, in general, weaken it materially; this is a defect, however, which can be readily detected.

---

* Cast-iron experiments ordered, by the House of Commons, to be printed, July 30, 1858.

In the experiments on pillars with flat ends, much care was taken to have the weight uniformly distributed over the whole area of the metal at the ends; this is not an easy matter to accomplish in so unyielding a material as cast-iron; it can be most readily done by interposing a plate of more ductile metal, such as copper, between the two surfaces of cast-iron. Although this was not done in testing the experimental pillars, there can be no doubt but that they were much better fitted in this respect than can be expected in ordinary practice.

The experimental pillars were tested in a rigid iron frame, which must have secured them from sensible vibration, except for the moments when the weights were applied. In many structures in which cast-iron pillars are used, such as factories, they are pretty constantly subject to vibration; what effect this has in weakening the pillar, it is not easy to estimate; the additional strain tending to produce fracture by lateral flexure must be in some proportion to the amplitude of the vibrations; in pillars of ordinary length and size, such as are commonly used in factories, the amplitudes of the vibrations are very small; although they may be very sensible to the touch, they are usually too small to be detected by the eye; this being the case, it would appear that, ordinarily, the additional strain due to the vibration is very small. It has been a common opinion that long-continued vibration, although very small in amplitude, causes a change in the structure of iron, rendering it more liable to break; of late, however, this notion appears to have been abandoned by those best informed.

In testing the experimental pillars, sufficient weight was applied to break the pillar in a short time, and it is certain that a somewhat less weight would have produced fracture in each case, if applied during a sufficiently long period of time. Fairbairn made some experiments on this point.* He loaded a pillar with 97 per cent of the weight which had previously broken another pillar of the same dimensions; it bore this weight between five and six months, and then broke. In another pillar, loaded with 75 per cent of the weight which had broken another of the same dimensions, at the end of three years its lateral deflection was still increasing slightly; this does not indicate, however, that it would ultimately fail, as we find the deflection of bars of cast-iron subject to a lateral strain increasing for a much longer time, although loaded with from 70 to 96 per cent of the weight which broke another bar of the same dimensions and material. Fairbairn,* referring to his experiments on the progressive deflection of bars of cast-iron, subjected to a transverse strain for a period of about five years, remarks as follows: —

---

* Tredgold on Cast-iron. Part II., 4th London edition.

"Viewing the whole of these experiments in relation to the solution of a problem affecting the laws which regulate the resistance of bodies to continuous strain, it is important to observe how admirably the cohesive powers of matter adapt themselves to circumstances, and with what tenacity they resist forces tending to dissever and rupture their parts.

"It is still a question for consideration how far this power extends, and whether or not bodies, when loaded within even $\frac{1}{1000}$ part of their breaking weight, would sustain the load forever, provided that no disturbing cause were present to produce fracture.

"I am strongly inclined to think that such would be the case, notwithstanding the fact that the whole of the loaded bars exhibit a progressive increase of deflection, which fact I am disposed to attribute to the vibrations continually going on in the building where the bars were fixed, and to those atmospheric changes, such as temperature, oxidation, &c., to which every description of material is subject."

I think we may safely infer that a pillar, not subject to disturbances, may be loaded with a very large proportion of its breaking weight, say $\frac{9}{10}$, or more, for a time indefinitely long without breaking; but that a pillar, loaded with a weight a very little less than just sufficient to break it in a short time, will be liable to break within an indefinitely long time; and that this time will be much shortened if the pillar is subject to vibration.

Pillars in some situations, such as warehouses, are subject to concussions from bodies falling on a floor above; the effect of this on the pillar would be much weakened by the mass of the floor, and it can scarcely happen when the pillar is otherwise loaded to the full extent it is designed to support.

We have seen that the formulas for the breaking weight are deduced from experiments made on small pillars, very carefully cast from iron of superior quality; when the same formulas are applied to pillars made of iron of inferior quality for the purpose, and are less carefully cast, it is reasonable to expect that the computed breaking weight will be too great. From what has been stated above, however, it may be inferred that, if the pillars are cast straight and sound, they will, in general, be as strong when made of the cheaper material and by the cheaper mode of casting, as the experimental pillars of Hodgkinson.

---

* On the Application of Cast and Wrought Iron to Building Purposes. By William Fairbairn. London, 1854.

We have seen, also, that when the formulas were applied to experimental pillars of somewhat larger dimensions than those from which the formulas were deduced, cast from different kinds of iron, that the actual breaking weights generally exceeded the breaking weights computed by the formulas.

In practice pillars are subject to the effects of vibration and time, which tend to cause them to fail when loaded with less than the computed breaking weights.

What allowance should be made to cover all unfavorable influences, and to afford sufficient surplus strength to insure complete security against failure, is a matter of opinion, and one in which the most experienced and skilful may differ widely.

In 1847, a commission was appointed by the British government to inquire into the application of iron to railway structures. This commission obtained the opinions of the most eminent English engineers and constructors, and in the appendix to their report* they give the following analysis of the evidence relating to cast-iron beams or girders: —

"There appears to be a considerable difference of opinion as to the proportion between the greatest load which a girder should be allowed to bear and the breaking weight. There are two conditions under which the weight may be applied, viz.: 1st, when stationary, as in the case of water-tanks, floors, &c.; 2d, when the weight moves so as to cause concussions and vibrations, as in railway bridges. In girders required for the first case, Mr. Fox and Mr. T. Cubitt consider that the breaking weight should be three times the greatest load; Mr. P. W. Barlow, four times; and Mr. Glynn would not make it less than five times the load.

"In girders for railway bridges, Mr. Brunel states that he allows the load to be $\frac{1}{3}$, or $\frac{2}{5}$, of the breaking weight; but he considers that the rule he adopts for calculating the dimensions of his girders gives more than the usual strength. Mr. Grissell and Mr. Charles May consider

---

* Report of the Commissioners appointed to inquire into the Application of Iron to Railway Structures. London, 1849.

$\frac{1}{3}$ to be sufficient; Mr. Rastrick, Mr. P. W. Barlow, Mr. R. Stephenson, and Mr. Joseph Cubitt adopt $\frac{1}{6}$; Mr. Hawkshaw prefers $\frac{1}{7}$, except in cases where great care is exercised in the selection of materials and workmanship, when a smaller proportion would suffice; and Mr. Glynn considers that, in structures exposed to concussion and vibration, the ultimate strength of a girder should be 10 times the greatest load."

Defects in material and workmanship are as likely to occur in girders as in pillars, and, with the exception of defective alignment, the defects in girders must be at least as injurious, and require as large an allowance of surplus strength to provide for them as is required to afford the same degree of security in pillars. In determining the proper allowance to be made for security, regard should be had to the consequences of failure. In most of the large modern buildings erected for commercial and industrial purposes, cast-iron pillars are extensively used for supporting the floors, and in many cases the walls of the upper stories are supported in the same manner. The failure of the pillars, in such cases, involves such disastrous consequences, that no economical considerations would warrant the use of pillars of insufficient or doubtful strength.

It is possible that a single pillar, although ample to support the superincumbent weight, may be broken by a lateral blow; in such an event, the neighboring pillars will usually have a large additional weight thrown upon them, and if they have not considerable surplus strength, the whole structure may be involved in ruin.

These considerations apply to girders as well as pillars, and no doubt they were taken into account by the experienced men whose opinions have been quoted.

It is very obvious that a large allowance of surplus strength must be provided to insure the complete security of a building depending for support on cast-iron pillars; the various considerations which have been offered do not, however, afford any definite data for determining the amount of this allowance. The only safe course is to rely upon the practice and opinions of experienced engineers and constructors. Taking all things into account it appears to me that, in pillars made with ordinary care to support walls and floors, to insure complete security without using more material than is necessary, the greatest load should be about one fifth of the computed breaking weight; and I have adopted this as the rule in computing the following tables.

Whatever allowance of surplus strength may be made for defects, there must be some assurance that the pillars will be cast with, at least, ordinary care. The best guaranty is to employ a founder of known skill and integrity. Some defects can be readily detected by inspection. Pillars having considerable imperfections in the casting should, of course, be rejected. In moulding hollow pillars of ordinary dimensions, the core should be made in one piece; if of more than one piece lengthwise, there is danger of injurious irregularities in the thickness at the junctions of the several parts. In moulding long hollow pillars, it is usual to insert small pieces of iron, called chaplets, to prevent the rising of the core, which, in pillars cast horizontally, is the principal cause of irregularity in the thickness; the chaplets remain, and form part of the pillar; they are frequently the cause of imperfections in the casting, but without using them it appears to be impracticable to make the iron of uniform thickness; a considerable inequality, however, in this respect does not weaken the pillar materially; but it should not be inferred, because Hodgkinson found that pillars in which the thickness on opposite sides varied as much as 3 to 1, were not sensibly weaker than those in which the thickness was uniform, that this irregularity may be disregarded; in Hodgkinson's experiments great care was taken to make sound castings, and also to make the pillars straight, often by turning them in a lathe when not cast straight. Some inequality in thickness must, however, be admitted, if the pillars are cast without chaplets; the extent of the inequality can be ascertained by means of long callipers; in my opinion it should not exceed the proportion of 2 to 1.

Cast-iron pillars are liable to be made crooked from two causes, well known to founders. If the iron is much thicker on one side of a hollow pillar than on the other, the thick side cooling last strains the thin side, and frequently produces a curvature. If the pillar is taken out of the mould while very hot, and laid on supports not furnishing a uniform bearing throughout its length, it is very liable to become bent. It is too much to expect that long pillars will be cast quite straight. I examined ten hollow pillars supporting five floors and the roof of a cotton-mill; I have no doubt they were cast with, at least, ordinary care; I found none of them quite straight. The pillars were about 11.5 feet long, 6 inches in diameter, and about 0.75 inch thick; the average deviation from a straight line in ten feet, which is all that could be conveniently measured, was about 0.03 foot; in other words, considering the axis to be the arc of a circle, the chord of which was 10 feet, the average versed sine was about 0.03 foot. In one pillar the deviation was about 0.08 foot. These pillars were well-fitted with flat ends, and loaded with less than one tenth of their computed breaking weight. A small part of the observed curvatures must have been due to the load. It may be necessary to admit a curvature when unloaded of $\frac{1}{300}$ of the length as a maximum, which in ten feet would give a versed sine of 0.033 foot.

It is usual to make round pillars a little smaller at the upper end than at the middle, frequently both ends are smaller; this is advantageous in strength with the same weight of iron, and also in appearance; the difference should not much exceed one tenth of the diameter. If smaller at both ends than at the middle, the surface of the pillar should be regularly curved from one end to the other; when so made a small deviation in the axis from a straight line is less observable.

In estimating the amount of the greatest load to which a pillar may be subjected, doubtful points should be taken on the safe side. In warehouses and stores, it would not be safe to take the ordinary load on the floors; they are liable to be packed full of heavy goods. When a warehouse or store is erected for a particular use, it will seldom be safe to estimate the weight due to that particular use; it should be made for the greatest weight due to any use to which such a building may be applied in the ordinary course of business. In modern cotton-mills with wooden floors I have found that the average weight, including the floor itself, the machinery, shafting, stock in process of manufacture, &c., is about 50 pounds per square foot of floor, and a flat roof when loaded with snow is liable to be as heavy. It is not safe, however, to take the average weight, as some pillars will have to support more and some less than the average; I think an addition of one fifth should be made to the average weight for the possible excess. In warehouses and stores, the weights to be provided for are usually much greater than in factories.

In pillars to support railway bridges, or other structures subject to violent concussions or vibrations, a less proportion than one fifth of the breaking weight should be allowed. In experiments on the deflections of railway bridges with a stationary load and with the same load moving at a high velocity, a greater deflection has been observed in the latter case, indicating a corresponding increase of the strain. The increased strain will, however, be principally felt in the girders, and will be only partially communicated to the pillars or other supports of the bridge.

Formulas (1) and (2) give the breaking weights of cast-iron pillars with the ends carefully fitted, so that the weight will be uniformly distributed on all sides; in ordinary constructions the ends are frequently unfinished, the inequalities in the bearing surfaces causing the weight to rest on a few points of the ends; the breaking weight of the pillar, in such case, cannot safely be taken as greater than that of a pillar with rounded ends, which, as we have seen, is about one third that of a pillar with flat ends. In cotton-mills, and many other structures largely supported by cast-iron pillars, the ends of the pillars are frequently turned, corresponding in this respect to the experimental pillars with flat ends; it would generally not be safe, however, to assume that they are as perfectly fitted as they were in the experiments; when put in place it must frequently happen that they will be canted a little, causing the bearing to fall on one edge; it will, accordingly, not be safe to assume that formulas (1) and (2) apply to this case without modification. If the ends are as perfectly fitted as they were in the experimental pillars, the breaking weight would be three times as great as in pillars with rounded ends; if one end is well fitted and the other end rounded, the breaking weight is twice that of pillars with both ends rounded; it would seem, therefore, that we may safely assume that, when pillars with flat ends are fitted and put up with ordinary care, they will support one and a half times as much as pillars with rounded ends, or, what is equivalent, one half the weight of pillars fitted and put up as perfectly as in the experiments.

The following tables have been computed by formulas (1) and (2), taking one third of the breaking weight as given by them for the breaking weight of a pillar with rounded ends, and one fifth of this last breaking weight as the safe weight for a pillar with rounded ends, or, what we assume to be equivalent, with the ends not turned. The safe weights for the other cases can be easily deduced from the same tables, as will be seen in the explanation of their use.

Tredgold's table was generally relied upon by constructors, until the publication of Hodgkinson's experiments. The same table reappears in the fourth edition of Tredgold's work, edited by Hodgkinson, with the note that "This table has no solid basis." As no other table is given, however, it is probable that its use has been continued by many persons not accustomed to such computations. Table V. contains a comparison of the safe weights, in tons of 2,000 pounds, which several solid pillars will support according to Tredgold's table, and according to Hodgkinson's formulas (1) and (2), taking one fifth of the breaking weight of a pillar with rounded ends as the safe weight. It will be seen that in the smaller pillars Tredgold gives a larger weight than according to Hodgkinson, while in the larger pillars Tredgold's weight is less than Hodgkinson's. It is remarkable, however, considering the origin of Tredgold's table, that they should differ so little.

TABLE V.

Diameter of the pillar.	Safe weight a pillar 8 feet long will support,		Safe weight a pillar 10 feet long will support,		Safe weight a pillar 12 feet long will support,	
	According to Tredgold.	According to Hodgkinson.	According to Tredgold.	According to Hodgkinson.	According to Tredgold.	According to Hodgkinson.
In.						
2.0	2.74	1.13	2.24	0.77	1.79	0.57
2.5	5.10	2.50	4.31	1.71	3.64	1.25
3.0	8.12	4.77	7.17	3.26	6.22	2.39
3.5	11.98	8.38	10.70	5.64	9.63	4.14
4.0	16.13	12.76	14.90	9.06	13.55	6.65
4.5	22.32	18.36	19.82	13.95	18.31	10.10
5.0	26.82	25.28	25.31	19.46	23.91	15.38
6.0	32.09	43.31	30.80	34.15	29.40	27.46
7.0	55.38	67.26	53.70	54.20	51.74	44.30
8.0	72.18	97.36	70.50	79.99	68.54	66.36
9.0	93.63	133.73	91.84	111.78	89.77	94.02
10.0	116.31	176.41	114.52	149.73	112.39	127.53

In the Journal of the Franklin Institute of Pennsylvania, commencing in the number for November, 1861, there have appeared a large number of interesting and useful tables relating to the strength of pillars of various materials, computed by the formulas of Hodgkinson, Tredgold, and others, by W. Bryson, Civ. Eng. These tables mostly give the breaking weights of solid pillars. Similar tables of more limited extent may be found in other works, but none of them appear to meet the wants of the practical man.

Use of the Following Tables.

The weights are given in lawful tons of the State of Massachusetts, viz. of 2,000 pounds avoirdupois, and are the weights which can be borne with safety by cylindrical cast-iron pillars made with ordinary care and with rounded ends, or what are assumed for this purpose to be equivalent, with ends not finished in planes at right angles to the axis, and the weight not uniformly distributed over the whole area of the ends.

Rule for Cylindrical Cast-iron Pillars.

For practical purposes we may divide the use of cylindrical cast-iron pillars into three cases: —

1. Pillars with rounded ends, or put up as they come from the founder, or with only the prominent irregularities at the ends chipped off, or however the ends may be, if the weight is very unequally distributed over their surfaces, or if unequal settlements may be apprehended. When the designer of the pillars has no control over the execution of the work or any guaranty that his directions will be minutely followed, his only safe course will be to consider them in this case. The weights given in the tables are the safe weights the pillars will support in this case.

2. Pillars with the ends turned in a lathe, to planes at right angles to the axes, and put up with ordinary care, so that the weight will be distributed over the whole area of the ends; the pillars being made and put up under the eye of the person responsible for their sufficiency, or with such other guaranty for faithful workmanship as may be satisfactory to him. In this case, it is assumed that the safe weight is one and a half times that for a pillar with rounded ends, and may be found from the tables by adding one half to the tabular weight.

3. Pillars with the ends finished, and put up with the degree of perfection attained in Hodgkinson's experiments on pillars with flat ends. The safe weight in this case is three times that given in the tables.

Note. The tables give the dimensions of several pillars of nearly equal strengths, from which, of course, may be selected the pillar deemed most suitable for the intended purpose. If the pillar is made a little smaller at one or both ends than in the middle, its strength will be nearly the same as that of a cylindrical pillar of the same length and of a diameter equal to its middle diameter.

Example. Required the dimensions of a pillar 12 feet long, the greatest load to be supported by it being 25 tons.

If in the first case, we find at the page of the table headed, "Cylindrical pillars of cast-iron 12 feet long," taking the tabular weights, nearest to, but not less than, 25 tons, that if solid, the pillar must be 6 inches in diameter; if $\frac{3}{4}$ inch thick, $7\frac{1}{2}$ inches in diameter; if 1 inch thick, $6\frac{3}{4}$ inches in diameter, &c.

If in the second case, take $\frac{2}{3}$ of 25 tons, which is 16.67 tons; proceeding in the same manner as in the first case, we find that, if solid, the pillar must be 5¼ inches in diameter; if ¾ inch thick, 6¼ inches in diameter; if 1 inch thick, 5¾ inches in diameter, &c.

If in the third case, take ⅓ of 25 tons, which is 8.33 tons; proceeding in the same manner, we find that, if solid, the pillar must be 4½ inches in diameter; if ¾ inch thick, 4¾ inches in diameter; if 1 inch thick, 4½ inches in diameter, &c.

In the absence of tables specially computed for the purpose, the use of the following tables may be extended to rectangular pillars of cast-iron, and to pillars both cylindrical and rectangular of some other materials.

Rule for Solid Square Cast-iron Pillars.

Calling the strength of a cylindrical pillar 100, the strength of a prismatic pillar of square section, whose side is equal to the diameter of the cylindrical pillar, according to different authorities, is as follows: —

According to Tredgold, when the distance of the direction of the force from the axis of the pillar is ⅛ of the diameter . .	146
Also, according to Tredgold, when the neutral axis is at or near the axis of the pillar	170
According to three experiments on square cast-iron pillars with rounded ends, given in Table III. of Hodgkinson's paper in Phil. Trans. for 1840	158
According to experiments on two square cast-iron pillars and two cylindrical cast-iron pillars, all with flat ends, given in the appendix to Hodgkinson's paper in Phil. Trans. for 1858 .	143

Assuming the proportion to be as 100 to 150, the safe weight which can be supported by a solid square cast-iron pillar is given by the following rule: —

Determine the weight for a cylindrical cast-iron pillar, of a diameter equal to the side of the square pillar, by the preceding rule for the particular case; add one half to this weight, the sum will be the weight for the square pillar.

Rule for Solid Prismatic Cast-iron Pillars, whose Section is a Rectangular Parallelogram.

Find, by the rule for square cast-iron pillars, the weight for a square pillar whose side is equal to the small side of the parallelogram; multiply this weight by the long side of the parallelogram, and divide the product by the small side; the quotient is the safe weight required.

Rule for Hollow Rectangular Pillars.

Find by the preceding rules the weights for solid pillars of the outside and inside dimensions of the hollow pillar; subtract one from the other; the difference will be the safe weight for the hollow pillar.

Rule for Solid Cylindrical Wrought-iron Pillars.

According to Hodgkinson, calling the strength of a cast-iron pillar 1000, the strength of a wrought-iron pillar of the same dimensions is 1745. Then to find the safe weight for a solid cylindrical wrought-iron pillar, find, by the preceding rules for cylindrical cast-iron pillars, the weight for a cast-iron pillar of the same dimensions; multiply this weight by 1.745; the product will be the safe weight for the wrought-iron pillar.

Note. This rule must be confined to pillars very long in proportion to their diameters; say, in pillars with flat ends, to lengths of not less than 60 diameters. Hodgkinson's experiments indicate that wrought-iron pillars with flat ends, of lengths equal to 30 diameters, are only about one tenth stronger than cast-iron pillars of the same dimensions. In a single experiment on a wrought-iron pillar with flat ends, of a length equal to about 15 diameters, the strength was nearly 40 per cent less than that of a like pillar of cast-iron. This great difference in the relative strengths of cast and wrought-iron pillars of different lengths in proportion to the diameters, arises from the greater strength of wrought-iron to resist a tensile force, and its less strength to resist a crushing force, the strength of short pillars depending mainly on the power of the material to resist the latter force.*

Rule for Solid Square Wrought-iron Pillars.

Find by the preceding rule the weight for a solid cylindrical pillar of wrought iron, whose diameter is equal to the side of the square pillar; add one half to this weight, the sum will be the safe weight for the square pillar. The length of the pillars to which this rule applies is subject to the same limitations as in the preceding rule.

---

* Strength of cast-iron (Low Moor, No. 3) to resist a crushing force 109,801 pounds per square inch; to resist a tensile force 14,535 pounds per square inch (Hodgkinson). Then crushing strength to tensile strength as 7.55 to 1.

Strength of wrought-iron to resist a crushing force 36,000 to 40,000 pounds per square inch; to resist a tensile force 60,000 to 70,000 pounds per square inch (Rankine). Then crushing strength to tensile strength about as 1 to 1.7.

Rule for Solid Cylindrical Cast-steel Pillars.

According to Hodgkinson, calling the strength of a cast-iron pillar 1000, the strength of a cast-steel pillar, not hardened, of the same dimensions, is 2518. Then to find the safe weight for a solid cylindrical cast-steel pillar, find, by the preceding rules for cylindrical cast-iron pillars, the weight for a cast-iron pillar of the same dimensions, multiply this weight by 2.518, the product will be the safe weight for the cast-steel pillar.

Rule for Solid Cylindrical Pillars of Dantzic Oak and Red Deal.[*]

According to Hodgkinson, calling the strength of a cast-iron pillar 1000, the strength of a pillar of the same dimensions of Dantzic Oak is 108.8 and of Red Deal 78.5. Then, to find the safe weight for solid cylindrical pillars of these materials, find, by the preceding rules for cylindrical pillars of cast-iron, the weight for a cast-iron pillar of the same dimensions; if for Dantzic Oak, divide this weight by nine, if for Red Deal, by thirteen, the quotient will be the safe weight for the wooden pillar.

Rule for Solid Square Pillars of Dantzic Oak and Red Deal.

Find the weight for a cylindrical pillar of a diameter equal to the side of the square pillar by the next preceding rule; add one half to this weight, the sum will be the safe weight for the square pillar.

---

[*] Barlow's formula for the breaking weight of a beam supported at each end and loaded in the middle is, $S = \frac{Wl}{4ad^2}$; in which S is a constant to be determined by experiment, W the breaking weight, l the length between the points of support, a the breadth and d the depth of the beam, the dimensions being all in inches.

For Dantzic oak (so called in England from the place of shipment), from experiments by Barlow and Moore . . . . . . S = 1518
For American White Oak (*Quercus alba*), from experiments by Nelson . . . . S = 1699
For Red Deal (*Pinus sylvestris*, Scotch Fir, Riga Fir), from experiments by Barlow . . . . S = 1165
For American White Pine (*Pinus strobus*), from experiments by Nelson . . . . S = 1456

The values of S do not necessarily give the relative strengths of different woods when used for pillars; they, however, afford some indication, and we may conclude, from the values quoted, that we may safely adopt the rule for pillars of Dantzic Oak for pillars of American White Oak, and the rule for pillars of Red Deal for pillars of American White Pine.

Cylindrical Pillars of

Safe weights, in tons of 2,000 pounds, which they can support, ing columns, in which the thickness of the iron is given in

Diameter of Pillar outside.	Solid.	⅜ Inch.	½ Inch.	⅝ Inch.	¾ Inch.	⅞ Inch.	1 Inch.	1⅛ Inch.
Inches.								
2	1.13	0.92	1.03					
2¼	1.72	1.31	1.50	1.62				
2½	2.50	1.79	2.09	2.28	2.40			
2¾	3.50	2.37	2.80	3.09	3.29	3.41		
3	4.77	3.05	3.64	4.07	4.36	4.56	4.67	
3¼	6.61	3.62	4.43	5.07	5.57	5.94	6.21	6.39
3½	8.38	4.30	5.30	6.12	6.77	7.28	7.66	7.94
3¾	10.42	5.03	6.24	7.25	8.08	8.74	9.26	9.66
4	12.76	5.79	7.24	8.46	9.48	10.32	11.00	11.53
4¼	15.40	6.60	8.28	9.73	10.97	12.00	12.86	13.55
4½	18.36	7.44	9.38	11.07	12.53	13.78	14.83	15.71
4¾	21.65	8.31	10.51	12.46	14.17	15.65	16.91	17.98
5	25.28	9.20	11.69	13.91	15.87	17.59	19.09	20.37
5¼	29.25	10.13	12.90	15.40	17.63	19.61	21.35	22.86
5½	33.57	11.07	14.15	16.94	19.45	21.69	23.69	25.45
5¾	38.26	12.04	15.42	18.51	21.31	23.84	26.10	28.12
6	43.31	13.02	16.72	20.12	23.22	26.03	28.58	30.86
6¼	48.73	14.02	18.04	21.75	25.16	28.28	31.11	33.67
6½	54.53	15.04	19.39	23.42	27.14	30.56	33.70	36.55
6¾	60.70	16.07	20.75	25.11	29.15	32.89	36.33	39.48
7	67.26	17.11	22.13	26.82	31.19	35.25	39.01	42.46
7¼	74.20	18.16	23.52	28.55	33.26	37.64	41.72	45.49
7½	81.53	19.22	24.93	30.30	35.35	40.06	44.47	48.56
7¾	89.25	20.29	26.35	32.07	37.45	42.51	47.24	51.66
8	97.36	21.36	27.78	33.85	39.58	44.98	50.05	54.80
8¼	105.87	22.45	29.22	35.64	41.72	47.46	52.88	57.96
8½	114.76	23.53	30.66	37.44	43.88	49.97	55.73	61.16
8¾	124.05	24.63	32.12	39.26	46.05	52.49	58.60	64.37
9	133.73	25.73	33.58	41.08	48.23	55.03	61.49	67.61
9¼	143.81	26.83	35.05	42.91	50.42	57.58	64.39	70.86
9½	154.28	27.95	36.52	44.75	52.62	60.14	67.31	74.13
9¾	165.15	29.05	38.00	46.59	54.83	62.71	70.24	77.42
10	176.41	30.16	39.48	48.44	57.04	65.28	73.18	80.72

Cast-iron **8** *feet long.*

if solid, as in the first column, or if hollow, as in the succeed-
the respective headings.

Diameter of Pillar outside.	1¼ Inch.	1⅜ Inch.	1½ Inch.	1⅝ Inch.	1¾ Inch.	1⅞ Inch.	2 Inch.
Inches.							
2							
2¼							
2½							
2¾							
3							
3¼							
3½	8.13						
3¾	9.95	10.15					
4	11.94	12.25	12.46				
4¼	14.10	14.53	14.84	15.08			
4½	16.42	16.99	17.43	17.76	18.01		
4¾	18.87	19.60	20.19	20.65	21.00	21.26	
5	21.46	22.37	23.12	23.73	24.21	24.58	24.86
5¼	24.17	25.28	26.21	26.98	27.61	28.11	28.50
5½	26.98	28.31	29.44	30.40	31.19	31.85	32.37
5¾	29.89	31.45	32.80	33.96	34.94	35.76	36.44
6	32.90	34.70	36.28	37.65	38.84	39.85	40.69
6¼	35.98	38.04	39.86	41.47	42.87	44.08	45.12
6½	39.13	41.46	43.55	45.40	47.03	48.46	49.70
6¾	42.36	44.96	47.32	49.43	51.30	52.97	54.43
7	45.64	48.53	51.17	53.54	55.68	57.59	59.28
7¼	48.97	52.16	55.09	57.75	60.15	62.32	64.26
7½	52.35	55.85	59.07	62.02	64.70	67.14	69.34
7¾	55.77	59.59	63.11	66.36	69.33	72.05	74.52
8	59.24	63.37	67.21	70.76	74.03	77.04	79.78
8¼	62.73	67.19	71.35	75.21	78.79	82.09	85.13
8½	66.26	71.05	75.54	79.72	83.61	87.21	90.54
8¾	69.82	74.95	79.76	84.27	88.47	92.39	96.02
9	73.40	78.87	84.01	88.85	93.38	97.62	101.56
9¼	77.00	82.81	88.30	93.47	98.33	102.89	107.16
9½	80.63	86.78	92.61	98.12	103.32	108.21	112.79
9¾	84.27	90.77	96.95	102.81	108.34	113.56	118.47
10	87.92	94.78	101.31	107.51	113.39	118.94	124.19

Cylindrical Pillars of

Safe weight, in tons of 2,000 pounds, which they can support, ing columns, in which the thickness of the iron is given in

Diameter of Pillar outside.	Solid.	⅜ Inch.	½ Inch.	⅝ Inch.	¾ Inch.	⅞ Inch.	1 Inch.	1⅛ Inch.
Inches.								
2	0.92	0.75	0.85					
2¼	1.41	1.07	1.23	1.33				
2½	2.04	1.47	1.71	1.87	1.96			
2¾	2.87	1.94	2.29	2.53	2.69	2.79		
3	3.90	2.50	2.98	3.33	3.57	3.73	3.82	
3¼	5.19	3.14	3.78	4.26	4.61	4.85	5.01	5.11
3½	6.75	3.88	4.70	5.34	5.82	6.17	6.41	6.57
3¾	8.95	4.39	5.44	6.31	7.01	7.57	8.01	8.34
4	11.00	5.08	6.34	7.39	8.27	8.98	9.56	10.01
4¼	13.32	5.82	7.29	8.55	9.61	10.50	11.23	11.81
4½	15.94	6.59	8.29	9.77	11.03	12.11	13.01	13.75
4¾	18.86	7.39	9.34	11.05	12.53	13.81	14.91	15.82
5	22.10	8.22	10.43	12.38	14.10	15.60	16.90	18.00
5¼	25.66	9.08	11.55	13.77	15.73	17.47	18.98	20.29
5½	29.55	9.97	12.72	15.20	17.42	19.40	21.15	22.68
5¾	33.78	10.88	13.91	16.67	19.16	21.40	23.39	25.16
6	38.36	11.81	15.14	18.19	20.95	23.46	25.71	27.72
6¼	43.30	12.76	16.39	19.73	22.79	25.57	28.09	30.36
6½	48.59	13.73	17.67	21,32	24.67	27.74	30.54	33.07
6¾	54.25	14.71	18.97	22.93	26.58	29.95	33.03	35.85
7	60.28	15.71	20.29	24.56	28.53	32.20	35.58	38.68
7¼	66.68	16.72	21.63	26.23	30.51	34.49	38.17	41.57
7½	73.46	17.74	22.99	27.91	32.51	36.81	40.80	44.50
7¾	80.62	18.78	24.36	29.62	34.55	39.16	43.47	47.48
8	88.16	19.83	25.75	31.34	36.60	41.55	46.18	50.50
8¼	96.09	20.88	27.15	33.08	38.68	43.95	48.91	53.56
8½	104.40	21.94	28.55	34.83	40.77	46.38	51.67	56.65
8¾	113.11	23.01	29.97	36.60	42.88	48.84	54.46	59.77
9	122.20	24.08	31.40	38.38	45.01	51.31	57.28	62.92
9¼	131.68	25.17	32.84	40.17	47.15	53.80	60.11	66.09
9½	141.56	26.25	34.29	41.97	49.31	56.30	62.96	69.29
9¾	151.83	27.33	35.74	43.78	51.48	58.82	65.83	72.50
10	162.50	28.44	37.20	45.60	53.65	61.36	68.72	75.74

Cast-iron **9** *feet long.*

if solid, as in the first column, or if hollow, as in the succeed-
the respective headings.

Diameter of Pillar outside.	1¼ Inch.	1⅜ Inch.	1½ Inch.	1⅝ Inch.	1¾ Inch.	1⅞ Inch.	2 Inch.
Inches.							
2							
2¼							
2½							
2¾							
3							
3¼							
3½	6.67						
3¾	8.57	8.74					
4	10.34	10.59	10.77				
4¼	12.27	12.62	12.88	13.07			
4½	14.35	14.83	15.19	15.47	15.66		
4¾	16.58	17.19	17.68	18.06	18.35	18.56	
5	18.94	19.71	20.34	20.85	21.25	21.55	21.77
5¼	21.42	22.37	23.16	23.81	24.33	24.75	25.07
5½	24.01	25.15	26.12	26.93	27.61	28.15	28.58
5¾	26.71	28.06	29.22	30.21	31.05	31.74	32.30
6	29.51	31.08	32.45	33.63	34.65	35.50	36.22
6¼	32.39	34.20	35.79	37.18	38.39	39.43	40.31
6½	35.36	37.41	39.24	40.86	42.27	43.50	44.57
6¾	38.40	40.71	42.79	44.64	46.28	47.72	48.98
7	41.52	44.09	46.43	48.52	50.40	52.06	53.53
7¼	44.69	47.54	50.15	52.50	54.62	56.53	58.22
7½	47.92	51.06	53.94	56.57	58.95	61.10	63.03
7¾	51.20	54.64	57.80	60.71	63.36	65.76	67.94
8	54.53	58.27	61.73	64.92	67.85	70.52	72.96
8¼	57.90	61.95	65.71	69.20	72.41	75.37	78.07
8½	61.31	65.68	69.75	73.53	77.04	80.28	83.27
8¾	64.76	69.45	73.83	77.93	81.74	85.27	88.54
9	68.24	73.25	77.96	82.37	86.48	90.32	93.88
9¼	71.75	77.09	82.12	86.85	91.28	95.43	99.29
9½	75.28	80.96	86.32	91.38	96.13	100.59	104.76
9¾	78.84	84.86	90.56	95.94	101.02	105.79	110.28
10	82.42	88.78	94.82	100.54	105.94	111.04	115.85

Cylindrical Pillars of

Safe weights, in tons of 2,000 pounds, which they can support, ing columns, in which the thickness of the iron is given in

Diameter of Pillar outside.	Solid.	⅜ Inch.	½ Inch.	⅝ Inch.	¾ Inch.	⅞ Inch.	1 Inch.	1⅛ Inch.
Inches.								
2	0.77	0.63	0.71					
2¼	1.17	0.90	1.03	1.11				
2½	1.71	1.23	1.43	1.56	1.64			
2¾	2.40	1.62	1.91	2.12	2.25	2.33		
3	3.26	2.09	2.49	2.78	2.98	3.12	3.20	
3¼	4.34	2.63	3.16	3.56	3.85	4.06	4.19	4.27
3½	5.64	3.24	3.93	4.47	4.87	5.16	5.36	5.50
3¾	7.21	3.94	4.81	5.50	6.03	6.43	6.72	6.93
4	9.06	4.73	5.80	6.67	7.35	7.89	8.29	8.58
4¼	11.63	5.16	6.45	7.55	8.48	9.25	9.87	10.37
4½	13.95	5.86	7.36	8.66	9.77	10.71	11.49	12.12
4¾	16.56	6.60	8.33	9.83	11.14	12.26	13.21	14.00
5	19.46	7.37	9.33	11.06	12.58	13.90	15.03	15.99
5¼	22.65	8.17	10.38	12.35	14.09	15.62	16.95	18.09
5½	26.16	9.00	11.46	13.68	15.66	17.41	18.95	20.29
5¾	29.99	9.85	12.58	15.06	17.28	19.27	21.03	22.59
6	34.15	10.73	13.74	16.47	18.96	21.19	23.20	24.98
6¼	38.64	11.63	14.92	17.93	20.68	23.18	25.43	27.44
6½	43.48	12.54	16.13	19.43	22.45	25.21	27.72	29.99
6¾	48.66	13.48	17.36	20.96	24.27	27.30	30.08	32.60
7	54.20	14.43	18.62	22.52	26.12	29.44	32.49	35.28
7¼	60.10	15.40	19.90	24.10	28.00	31.62	34.95	38.02
7½	66.36	16.39	21.21	25.72	29.92	33.84	37.46	40.82
7¾	72.99	17.38	22.52	27.35	31.87	36.09	40.02	43.66
8	79.99	18.39	23.86	29.01	33.85	38.38	42.61	46.56
8¼	87.37	19.41	25.21	30.69	35.85	40.70	45.24	49.49
8½	95.12	20.44	26.58	32.39	37.87	43.05	47.91	52.47
8¾	103.26	21.48	27.96	34.10	39.92	45.42	50.60	55.48
9	111.78	22.53	29.35	35.83	41.99	47.82	53.33	58.53
9¼	120.68	23.58	30.75	37.58	44.07	50.24	56.08	61.60
9½	129.98	24.64	32.16	39.33	46.17	52.67	58.85	64.71
9¾	139.66	25.71	33.58	41.10	48.29	55.13	61.65	67.84
10	149.73	26.79	35.01	42.88	50.41	57.61	64.47	71.00

Cast-iron **10** *feet long.*

if solid, as in the first column, or if hollow, as in the succeed-
the respective headings.

Diameter of Pillar outside.	1¼ Inch.	1⅜ Inch.	1½ Inch.	1⅝ Inch.	1¾ Inch.	1⅞ Inch.	2 Inch.
Inches.							
2							
2¼							
2½							
2¾							
3							
3¼							
3½	5.57						
3¾	7.06	7.14					
4	8.78	8.92	9.00				
4¼	10.76	11.06	11.27	11.43			
4½	12.64	13.04	13.35	13.57	13.73		
4¾	14.65	15.18	15.59	15.91	16.15	16.32	
5	16.80	17.46	18.00	18.43	18.76	19.01	19.20
5¼	19.07	19.89	20.57	21.12	21.57	21.91	22.18
5½	21.46	22.45	23.28	23.98	24.55	25.01	25.37
5¾	23.95	25.13	26.14	26.99	27.71	28.30	28.77
6	26.55	27.93	29.12	30.15	31.03	31.76	32.37
6¼	29.24	30.83	32.23	33.45	34.49	35.39	36.14
6½	32.02	33.84	35.45	36.87	38.10	39.17	40.09
6¾	34.89	36.94	38.78	40.41	41.85	43.10	44.20
7	37.82	40.12	42.20	44.06	45.71	47.17	48.45
7¼	40.83	43.39	45.71	47.81	49.69	51.37	52.85
7½	43.90	46.73	49.31	51.65	53.77	55.68	57.38
7¾	47.03	50.14	52.98	55.59	57.95	60.10	62.03
8	50.22	53.60	56.73	59.60	62.23	64.62	66.79
8¼	53.45	57.13	60.54	63.69	66.58	62.23	71.65
8½	56.73	60.71	64.41	67.84	71.01	73.93	76.61
8¾	60.06	64.34	68.34	72.06	75.52	78.71	81.66
9	63.42	68.02	72.32	76.34	80.09	83.57	86.79
9¼	66.82	71.73	76.35	80.67	84.72	88.49	91.99
9½	70.25	75.49	80.42	85.05	89.40	93.47	97.27
9¾	73.71	79.28	84.53	89.48	94.14	98.51	102.60
10	77.20	83.10	88.67	93.95	98.92	103.60	108.00

Cylindrical Pillars of

Safe weights, in tons of 2,000 pounds, which they can support, ing columns, in which the thickness of the iron is given in

Diameter of Pillar outside.	Solid.	3/8 Inch.	1/2 Inch.	5/8 Inch.	3/4 Inch.	7/8 Inch.	1 Inch.	1 1/8 Inch.
Inches.								
2	0.66	0.53	0.60					
2 1/4	1.00	0.76	0.88	0.94				
2 1/2	1.45	1.04	1.22	1.33	1.40			
2 3/4	2.04	1.38	1.63	1.80	1.91	1.98		
3	2.77	1.78	2.12	2.36	2.54	2.65	2.72	
3 1/4	3.69	2.23	2.69	3.03	3.28	3.45	3.56	3.63
3 1/2	4.80	2.76	3.34	3.80	4.14	4.39	4.56	4.67
3 3/4	6.13	3.35	4.09	4.68	5.13	5.47	5.72	5.89
4	7.71	4.02	4.93	5.67	6.25	6.71	7.05	7.30
4 1/4	9.56	4.76	5.87	6.78	7.52	8.10	8.56	8.90
4 1/2	12.31	5.24	6.58	7.73	8.70	9.52	10.20	10.76
4 3/4	14.64	5.92	7.46	8.80	9.96	10.94	11.77	12.46
5	17.24	6.64	8.39	9.93	11.28	12.44	13.44	14.28
5 1/4	20.13	7.38	9.36	11.12	12.67	14.03	15.20	16.21
5 1/2	23.30	8.15	10.37	12.35	14.12	15.68	17.05	18.24
5 3/4	26.77	8.95	11.41	13.64	15.63	17.41	18.98	20.36
6	30.55	9.77	12.49	14.96	17.20	19.20	20.99	22.58
6 1/4	34.64	10.62	13.61	16.34	18.82	21.06	23.08	24.88
6 1/2	39.06	11.49	14.75	17.74	20.48	22.97	25.23	27.26
6 3/4	43.82	12.37	15.92	19.19	22.19	24.94	27.45	29.72
7	48.91	13.28	17.11	20.67	23.95	26.96	29.72	32.24
7 1/4	54.34	14.20	18.33	22.18	25.74	29.03	32.06	34.83
7 1/2	60.12	15.14	19.58	23.71	27.57	31.14	34.44	37.49
7 3/4	66.26	16.10	20.84	25.28	29.43	33.29	36.88	40.19
8	72.76	17.07	22.12	26.87	31.32	35.48	39.35	42.95
8 1/4	79.62	18.05	23.42	28.49	33.24	37.70	41.88	45.77
8 1/2	86.84	19.04	24.74	30.12	35.19	39.96	44.43	48.62
8 3/4	94.44	20.05	26.07	31.78	37.17	42.25	47.03	51.52
9	102.41	21.06	27.42	33.45	39.16	44.56	49.66	54.45
9 1/4	110.76	22.09	28.78	35.14	41.18	46.90	52.32	57.42
9 1/2	119.49	23.12	30.15	36.85	43.22	49.27	55.00	60.43
9 3/4	128.60	24.17	31.54	38.57	45.28	51.66	57.72	63.47
10	138.09	25.21	32.93	40.31	47.35	54.06	60.46	66.53

Cast-iron **11** *feet long.*

if solid, as in the first column, or if hollow, as in the succeed- the respective headings.

Diameter of Pillar outside.	1¼ Inch.	1⅜ Inch.	1½ Inch.	1⅝ Inch.	1¾ Inch.	1⅞ Inch.	2 Inch.
Inches.							
2							
2¼							
2½							
2¾							
3							
3¼							
3½	4.74						
3¾	6.00	6.07					
4	7.47	7.58	7.65				
4¼	9.15	9.32	9.43	9.50			
4½	11.20	11.54	11.80	12.00	12.13		
4¾	13.03	13.48	13.83	14.10	14.30	14.45	
5	14.98	15.56	16.02	16.39	16.67	16.88	17.03
5¼	17.06	17.78	18.36	18.84	19.22	19.51	19.73
5½	19.26	20.13	20.85	21.46	21.95	22.34	22.64
5¾	21.56	22.60	23.48	24.22	24.84	25.35	25.75
6	23.97	25.19	26.24	27.14	27.90	28.53	29.05
6¼	26.48	27.89	29.12	30.19	31.11	31.88	32.53
6½	29.08	30.70	32.12	33.37	34.46	35.39	36.19
6¾	31.76	33.60	35.23	36.68	37.95	39.05	40.01
7	34.53	36.59	38.44	40.10	41.56	42.85	43.98
7¼	37.37	39.67	41.75	43.62	45.30	46.78	48.09
7½	40.28	42.83	45.15	47.25	49.15	50.84	52.35
7¾	43.25	46.06	48.63	50.97	53.10	55.01	56.73
8	46.29	49.37	52.19	54.78	57.15	59.29	61.23
8¼	49.38	52.73	55.83	58.68	61.29	63.67	65.84
8½	52.52	56.16	59.53	62.64	65.52	68.15	70.56
8¾	55.72	59.64	63.29	66.68	69.82	72.71	75.37
9	58.96	63.17	67.12	70.79	74.20	77.36	80.28
9¼	62.23	66.75	71.00	74.95	78.65	82.08	85.27
9½	65.55	70.38	74.92	79.18	83.16	86.88	90.34
9¾	68.91	74.05	78.89	83.45	87.73	91.74	95.48
10	72.30	77.75	82.91	87.78	92.36	96.66	100.69

Cylindrical Pillars of

Safe weights, in tons of 2,000 pounds, which they can support, ing columns, in which the thickness of the iron is given in

Diameter of Pillar outside.	Solid.	⅜ Inch.	½ Inch.	⅝ Inch.	¾ Inch.	⅞ Inch.	1 Inch.	1⅛ Inch.
Inches.								
2	0.57	0.46	0.52					
2¼	0.86	0.66	0.75	0.81				
2½	1.25	0.90	1.05	1.15	1.20			
2¾	1.76	1.19	1.40	1.55	1.65	1.71		
3	2.39	1.53	1.83	2.04	2.19	2.29	2.34	
3¼	3.18	1.93	2.32	2.61	2.83	2.98	3.07	3.13
3½	4.14	2.38	2.88	3.27	3.57	3.78	3.93	4.03
3¾	5.29	2.89	3.53	4.03	4.42	4.72	4.93	5.08
4	6.65	3.47	4.25	4.89	5.39	5.78	6.08	6.29
4¼	8.24	4.10	5.06	5.85	6.48	6.99	7.38	7.67
4½	10.10	4.81	5.96	6.92	7.70	8.34	8.84	9.23
4¾	12.23	5.59	6.95	8.10	9.05	9.84	10.48	10.98
5	15.38	6.00	7.57	8.96	10.16	11.19	12.08	12.82
5¼	17.99	6.69	8.47	10.05	11.44	12.65	13.70	14.59
5½	20.86	7.40	9.41	11.20	12.78	14.18	15.40	16.46
5¾	24.02	8.15	10.38	12.39	14.19	15.79	17.19	18.42
6	27.46	8.92	11.39	13.63	15.65	17.46	19.06	20.48
6¼	31.21	9.72	12.44	14.92	17.17	19.19	21.01	22.63
6½	35.25	10.54	13.51	16.24	18.73	20.99	23.02	24.85
6¾	39.61	11.37	14.62	17.61	20.34	22.84	25.11	27.16
7	44.30	12.24	15.75	19.00	22.00	24.74	27.25	29.53
7¼	49.30	13.11	16.91	20.44	23.70	26.70	29.46	31.98
7½	54.65	14.01	18.10	21.90	25.43	28.70	31.72	34.49
7¾	60.33	14.92	19.30	23.39	27.21	30.75	34.03	37.06
8	66.36	15.85	20.53	24.91	29.01	32.84	36.39	39.69
8¼	72.74	16.80	21.78	26.46	30.85	34.96	38.80	42.37
8½	79.47	17.75	23.04	28.03	32.72	37.13	41.25	45.09
8¾	86.56	18.72	24.33	29.62	34.62	39.32	43.74	47.87
9	94.02	19.70	25.63	31.24	36.54	41.55	46.26	50.69
9¼	101.84	20.70	26.94	32.87	38.49	43.81	48.83	53.55
9½	110.03	21.70	28.27	34.53	40.46	46.09	51.42	56.45
9¾	118.59	22.71	29.61	36.19	42.46	48.40	54.05	59.38
10	127.53	23.73	30.97	37.88	44.47	50.74	56.70	62.35

Cast-iron **12** *feet long.*

if solid, as in the first column, or if hollow, as in the succeed-
the respective headings.

Diameter of Pillar outside.	1¼ Inch.	1⅜ Inch.	1½ Inch.	1⅝ Inch.	1¾ Inch.	1⅞ Inch.	2 Inch.
Inches.							
2							
2¼							
2½							
2¾							
3							
3¼							
3½	4.09						
3¾	5.18	5.24					
4	6.44	6.54	6.60				
4¼	7.89	8.04	8.14	8.19			
4½	9.53	9.74	9.89	9.99	10.05		
4¾	11.37	11.66	11.88	12.03	12.13	12.18	
5	13.44	13.94	14.34	14.66	14.90	15.08	15.21
5¼	15.34	15.97	16.48	16.90	17.22	17.47	17.66
5½	17.36	18.13	18.77	19.29	19.72	20.05	20.32
5¾	19.49	20.41	21.19	21.84	22.38	22.81	23.16
6	21.73	22.81	23.73	24.53	25.19	25.74	26.20
6¼	24.06	25.31	26.41	27.35	28.16	28.84	29.41
6½	26.48	27.93	29.20	30.31	31.27	32.09	32.79
6¾	29.00	30.64	32.11	33.39	34.52	35.50	36.33
7	31.60	33.45	35.11	36.59	37.90	39.04	40.04
7¼	34.27	36.35	38.22	39.90	41.40	42.72	43.88
7½	37.02	39.33	41.43	43.32	45.02	46.53	47.88
7¾	39.84	42.39	44.72	46.83	48.74	50.46	52.00
8	42.73	45.53	48.10	50.44	52.57	54.50	56.24
8¼	45.67	48.73	51.55	54.14	56.50	58.65	60.61
8½	48.68	52.00	55.08	57.91	60.52	62.91	65.08
8¾	51.73	55.33	58.67	61.77	64.62	67.25	69.66
9	54.84	58.72	62.33	65.69	68.81	71.69	74.34
9¼	57.99	62.16	66.05	69.69	73.07	76.21	79.11
9½	61.19	65.65	69.83	73.74	77.40	80.80	83.96
9¾	64.43	69.19	73.66	77.86	81.80	85.47	88.90
10	67.71	72.77	77.54	82.03	86.26	90.21	93.91

Cylindrical Pillars of

Safe weights, in tons of 2,000 pounds, which they can support,
ing columns, in which the thickness of the iron is given in

Diameter of Pillar outside.	Solid.	⅜ Inch.	½ Inch.	⅝ Inch.	¾ Inch.	⅞ Inch.	1 Inch.	1⅛ Inch.
Inches.								
2	0.49	0.40	0.45					
2¼	0.75	0.57	0.66	0.71				
2½	1.09	0.79	0.92	1.00	1.05			
2¾	1.53	1.04	1.23	1.36	1.44	1.49		
3	2.09	1.34	1.59	1.78	1.91	2.00	2.05	
3¼	2.78	1.68	2.02	2.28	2.47	2.60	2.68	2.73
3½	3.61	2.08	2.52	2.86	3.12	3.30	3.43	3.52
3¾	4.61	2.52	3.08	3.52	3.86	4.12	4.30	4.43
4	5.80	3.02	3.71	4.27	4.71	5.05	5.31	5.49
4¼	7.19	3.58	4.42	5.10	5.66	6.10	6.44	6.70
4½	8.81	4.20	5.20	6.04	6.72	7.28	7.72	8.06
4¾	10.68	4.88	6.06	7.07	7.90	8.59	9.14	9.58
5	12.81	5.62	7.01	8.20	9.20	10.03	10.72	11.28
5¼	16.17	6.08	7.70	9.12	10.37	11.46	12.40	13.19
5½	18.78	6.75	8.57	10.19	11.62	12.88	13.97	14.92
5¾	21.66	7.45	9.48	11.30	12.93	14.37	15.63	16.74
6	24.81	8.17	10.42	12.46	14.29	15.92	17.37	18.65
6¼	28.23	8.91	11.40	13.66	15.70	17.54	19.18	20.64
6½	31.95	9.69	12.41	14.91	17.17	19.22	21.07	22.72
6¾	35.96	10.48	13.46	16.19	18.69	20.96	23.02	24.88
7	40.27	11.29	14.53	17.51	20.25	22.76	25.04	27.12
7¼	44.90	12.13	15.63	18.87	21.86	24.60	27.12	29.42
7½	49.84	12.98	16.75	20.26	23.50	26.50	29.26	31.79
7¾	55.11	13.85	17.90	21.68	25.19	28.45	31.45	34.23
8	60.70	14.74	19.07	23.13	26.91	30.43	33.70	36.72
8¼	66.64	15.64	20.27	24.61	28.67	32.46	35.99	39.27
8½	72.91	16.56	21.48	26.11	30.46	34.53	38.33	41.87
8¾	79.53	17.49	22.71	27.64	32.28	36.63	40.71	44.53
9	86.50	18.44	23.97	29.19	34.13	38.77	43.14	47.23
9¼	93.82	19.40	25.23	30.77	36.00	40.94	45.60	49.98
9½	101.51	20.37	26.52	32.36	37.90	43.14	48.10	52.77
9¾	109.55	21.35	27.82	33.98	39.83	45.38	50.63	55.60
10	117.96	22.34	29.13	35.61	41.77	47.63	53.20	58.46

Cast-iron **13** *feet long.*

if solid, as in the first column, or if hollow, as in the succeed-
the respective headings.

Diameter of Pillar outside.	1¼ Inch.	1⅜ Inch.	1½ Inch.	1⅝ Inch.	1¾ Inch.	1⅞ Inch.	2 Inch.
Inches.							
2							
2¼							
2½							
2¾							
3							
3¼							
3½	3.57						
3¾	4.52	4.57					
4	5.62	5.71	5.76				
4¼	6.89	7.02	7.10	7.15			
4½	8.32	8.50	8.63	8.72	8.77		
4¾	9.92	10.18	10.37	10.50	10.58	10.63	
5	11.72	12.06	12.31	12.50	12.63	12.72	12.77
5¼	13.86	14.41	14.87	15.23	15.52	15.73	15.89
5½	15.72	16.40	16.97	17.43	17.80	18.09	18.32
5¾	17.69	18.51	19.20	19.77	20.25	20.63	20.93
6	19.76	20.73	21.55	22.26	22.84	23.33	23.72
6¼	21.93	23.06	24.03	24.87	25.59	26.19	26.69
6½	24.20	25.49	26.63	27.62	28.48	29.21	29.82
6¾	26.55	28.03	29.34	30.50	31.50	32.37	33.11
7	28.99	30.66	32.16	33.49	34.66	35.68	36.56
7¼	31.50	33.39	35.08	36.59	37.94	39.12	40.16
7½	34.10	36.20	38.10	39.81	41.34	42.70	43.90
7¾	36.77	39.09	41.21	43.12	44.85	46.39	47.77
8	39.50	42.06	44.40	46.53	48.46	50.21	51.77
8¼	42.30	45.10	47.68	50.03	52.18	54.13	55.89
8½	45.17	48.22	51.03	53.62	56.00	58.16	60.13
8¾	48.09	51.39	54.46	57.29	59.90	62.29	64.48
9	51.06	54.63	57.96	61.04	63.89	66.52	68.93
9¼	54.08	57.93	61.52	64.86	67.96	70.83	73.48
9½	57.16	61.28	65.14	68.75	72.11	75.23	78.12
9¾	60.28	64.68	68.82	72.70	76.33	79.70	82.85
10	63.44	68.14	72.56	76.71	80.61	84.26	87.66

Cylindrical Pillars of

Safe weights, in tons of 2,000 pounds, which they can support, ing columns, in which the thickness of the iron is given in

Diameter of Pillar outside. Inches.	Solid.	⅜ Inch.	½ Inch.	⅝ Inch.	¾ Inch.	⅞ Inch.	1 Inch.	1⅛ Inch.
2	0.44	0.35	0.40					
2¼	0.66	0.51	0.58	0.63				
2½	0.96	0.69	0.81	0.88	0.93			
2¾	1.35	0.91	1.08	1.19	1.27	1.31		
3	1.84	1.18	1.40	1.57	1.68	1.76	1.80	
3¼	2.45	1.48	1.78	2.01	2.17	2.29	2.36	2.41
3½	3.18	1.83	2.20	2.52	2.75	2.91	3.03	3.10
3¾	4.07	2.22	2.71	3.10	3.40	3.63	3.79	3.91
4	5.11	2.67	3.27	3.76	4.15	4.45	4.68	4.84
4¼	6.34	3.16	3.90	4.50	4.99	5.38	5.68	5.81
4½	7.77	3.70	4.58	5.32	5.93	6.42	6.80	7.11
4¾	9.41	4.30	5.35	6.23	6.97	7.57	8.06	8.45
5	11.29	4.95	6.18	7.23	8.11	8.85	9.45	9.94
5¼	13.43	5.66	7.09	8.31	9.36	10.24	10.98	11.59
5½	15.84	6.43	8.07	9.50	10.73	11.77	12.66	13.39
5¾	19.63	6.82	8.68	10.34	11.82	13.12	14.27	15.26
6	22.51	7.50	9.56	11.42	13.09	14.57	15.88	17.04
6¼	25.65	8.20	10.48	12.55	14.41	16.08	17.58	18.90
6½	29.07	8.93	11.43	13.71	15.79	17.66	19.34	20.84
6¾	32.77	9.68	12.41	14.92	17.21	19.29	21.17	22.86
7	36.75	10.45	13.43	16.17	18.68	20.98	23.07	24.96
7¼	41.02	11.24	14.47	17.45	20.20	22.72	25.03	27.13
7½	45.60	12.05	15.53	18.77	21.76	24.52	27.05	29.37
7¾	50.49	12.88	16.63	20.12	23.36	26.36	29.13	31.67
8	55.69	13.72	17.75	21.50	25.00	28.25	31.26	34.04
8¼	61.22	14.59	18.88	22.91	26.67	30.18	33.44	36.46
8½	67.07	15.47	20.05	24.35	28.38	32.15	35.67	38.94
8¾	73.25	16.36	21.23	25.81	30.12	34.17	37.95	41.48
9	79.77	17.27	22.43	27.30	31.90	36.22	40.27	44.06
9¼	86.63	18.19	23.65	28.82	33.70	38.30	42.63	46.69
9½	93.84	19.13	24.89	30.35	35.53	40.42	45.03	49.37
9¾	101.40	20.07	26.14	31.91	37.38	42.57	47.46	52.09
10	109.31	21.03	27.41	33.49	39.26	44.74	49.94	54.85

Cast-iron **14** *feet long.*

if solid, as in the first column, or if hollow, as in the succeed-
the respective headings.

Diameter of Pillar outside.	1¼ Inch.	1⅜ Inch.	1½ Inch.	1⅝ Inch.	1¾ Inch.	1⅞ Inch.	2 Inch.
Inches.							
2							
2¼							
2½							
2¾							
3							
3¼							
3½	3.15						
3¾	3.98	4.03					
4	4.96	5.03	5.08				
4¼	6.07	6.19	6.26	6.31			
4½	7.33	7.50	7.61	7.69	7.73		
4¾	8.75	8.98	9.14	9.26	9.33	9.39	
5	10.33	10.63	10.86	11.02	11.14	11.21	11.26
5¼	12.08	12.46	12.77	12.99	13.16	13.27	13.35
5½	14.00	14.49	14.88	15.18	15.40	15.57	15.68
5¾	16.12	16.85	17.46	17.98	18.40	18.73	19.00
6	18.04	18.91	19.65	20.28	20.80	21.23	21.57
6¼	20.06	21.07	21.95	22.70	23.34	23.87	24.31
6½	22.17	23.35	24.37	25.26	26.02	26.67	27.22
6¾	24.37	25.72	26.90	27.94	28.84	29.62	30.28
7	26.66	28.19	29.54	30.74	31.79	32.70	33.50
7¼	29.03	30.74	32.28	33.67	34.86	35.93	36.86
7½	31.48	33.39	35.12	36.67	38.05	39.28	40.36
7¾	34.00	36.12	38.05	39.79	41.36	42.76	44.00
8	36.59	38.93	41.07	43.01	44.77	46.35	47.76
8¼	39.25	41.82	44.18	46.33	48.29	50.06	51.66
8½	41.98	44.78	47.36	49.73	51.90	53.87	55.66
8¾	44.76	47.81	50.62	53.22	55.61	57.79	59.79
9	47.60	50.90	53.96	56.79	59.41	61.81	64.02
9¼	50.50	54.05	57.36	60.44	63.29	65.92	68.35
9½	53.44	57.26	60.83	64.16	67.25	70.12	72.77
9¾	56.44	60.53	64.36	67.95	71.29	74.40	77.29
10	59.48	63.85	67.95	71.80	75.40	78.77	81.90

Cylindrical Pillars of

Safe weights, in tons of 2,000 pounds, which they can support, ing columns, in which the thickness of the iron is given in

Diameter of Pillar outside.	Solid.	⅜ Inch.	½ Inch.	⅝ Inch.	¾ Inch.	⅞ Inch.	1 Inch.	1⅛ Inch.
Inches.								
2	0.39	0.32	0.36					
2¼	0.59	0.45	0.52	0.56				
2½	0.86	0.62	0.72	0.78	0.82			
2¾	1.20	0.81	0.96	1.06	1.13	1.17		
3	1.64	1.05	1.25	1.40	1.50	1.56	1.60	
3¼	2.18	1.32	1.59	1.79	1.93	2.04	2.10	2.14
3½	2.83	1.63	1.97	2.24	2.44	2.59	2.69	2.76
3¾	3.62	1.98	2.41	2.76	3.03	3.23	3.38	3.48
4	4.55	2.37	2.91	3.35	3.69	3.96	4.16	4.31
4¼	5.64	2.81	3.46	4.00	4.44	4.78	5.05	5.25
4½	6.91	3.29	4.08	4.73	5.27	5.71	6.05	6.32
4¾	8.37	3.82	4.75	5.54	6.20	6.73	7.17	7.51
5	10.04	4.40	5.50	6.43	7.21	7.87	8.41	8.84
5¼	11.94	5.03	6.30	7.39	8.33	9.11	9.77	10.30
5½	14.09	5.72	7.18	8.45	9.54	10.47	11.26	11.91
5¾	16.50	6.45	8.12	9.59	10.86	11.95	12.88	13.66
6	19.19	7.24	9.14	10.81	12.28	13.55	14.64	15.57
6¼	23.41	7.57	9.66	11.55	13.26	14.79	16.15	17.35
6½	26.56	8.25	10.55	12.65	14.55	16.27	17.80	19.17
6¾	29.97	8.95	11.48	13.79	15.89	17.80	19.52	21.07
7	33.65	9.68	12.43	14.96	17.28	19.39	21.31	23.04
7¼	37.62	10.43	13.42	16.18	18.71	21.03	23.15	25.08
7½	41.86	11.20	14.43	17.42	20.19	22.73	25.06	27.19
7¾	46.41	11.99	15.47	18.71	21.71	24.48	27.03	29.37
8	51.25	12.80	16.53	20.02	23.26	26.27	29.05	31.61
8¼	56.40	13.62	17.62	21.36	24.86	28.11	31.12	33.91
8½	61.86	14.46	18.73	22.74	26.49	29.99	33.25	36.27
8¾	67.63	15.32	19.86	24.14	28.15	31.91	35.42	38.69
9	73.74	16.19	21.02	25.57	29.85	33.87	37.63	41.15
9¼	80.17	17.08	22.19	27.02	31.58	35.87	39.89	43.67
9½	86.93	17.98	23.38	28.50	33.33	37.90	42.20	46.24
9¾	94.04	18.89	24.59	30.00	35.12	39.96	44.54	48.85
10	101.48	19.82	25.81	31.52	36.93	42.06	46.91	51.50

Cast-iron **15** *feet long.*

if solid, as in the first column, or if hollow, as in the succeed-
the respective headings.

Diameter of Pillar outside.	1¼ Inch.	1⅜ Inch.	1½ Inch.	1⅝ Inch.	1¾ Inch.	1⅞ Inch.	2 Inch.
Inches.							
2							
2¼							
2½							
2¾							
3							
3¼							
3½	2.80						
3¾	3.54	3.58					
4	4.41	4.48	4.52				
4¼	5.40	5.50	5.57	5.61			
4½	6.52	6.67	6.77	6.84	6.88		
4¾	7.78	7.98	8.13	8.23	8.30	8.34	
5	9.19	9.45	9.66	9.80	9.90	9.97	10.01
5¼	10.74	11.09	11.35	11.55	11.70	11.80	11.87
5½	12.45	12.88	13.23	13.50	13.70	13.85	13.95
5¾	14.32	14.86	15.29	15.64	15.91	16.11	16.25
6	16.35	17.01	17.55	17.98	18.33	18.60	18.80
6¼	18.41	19.33	20.12	20.80	21.37	21.84	22.24
6½	20.38	21.45	22.37	23.18	23.86	24.45	24.93
6¾	22.44	23.66	24.74	25.68	26.49	27.19	27.78
7	24.59	25.98	27.21	28.30	29.25	30.07	30.78
7¼	26.82	28.38	29.78	31.03	32.12	33.09	33.92
7½	29.12	30.87	32.45	33.86	35.12	36.23	37.21
7¾	31.51	33.45	35.21	36.80	38.23	39.50	40.62
8	33.96	36.11	38.07	39.84	41.45	42.89	44.17
8¼	36.48	38.85	41.01	42.98	44.77	46.39	47.84
8½	39.07	41.66	44.03	46.21	48.19	50.00	51.63
8¾	41.72	44.54	47.13	49.52	51.71	53.72	55.54
9	44.43	47.48	50.31	52.92	55.33	57.53	59.55
9¼	47.20	50.49	53.56	56.40	59.02	61.45	63.67
9½	50.02	53.57	56.87	59.95	62.81	65.45	67.89
9¾	52.90	56.70	60.25	63.58	66.67	69.54	72.20
10	55.82	59.88	63.70	67.27	70.61	73.72	76.61

Cylindrical Pillars of

Safe weights, in tons of 2,000 pounds, which they can support, ing columns, in which the thickness of the iron is given in

Diameter of Pillar outside.	Solid.	⅜ Inch.	½ Inch.	⅝ Inch.	¾ Inch.	⅞ Inch.	1 Inch.	1⅛ Inch.
Inches.								
2	0.35	0.28	0.32					
2¼	0.53	0.40	0.46	0.50				
2½	0.77	0.55	0.64	0.70	0.74			
2¾	1.08	0.73	0.86	0.95	1.01	1.05		
3	1.47	0.94	1.12	1.25	1.34	1.40	1.44	
3¼	1.95	1.18	1.42	1.60	1.73	1.82	1.88	1.92
3½	2.54	1.46	1.77	2.01	2.19	2.32	2.41	2.47
3¾	3.24	1.77	2.16	2.47	2.71	2.89	3.02	3.12
4	4.08	2.13	2.61	3.00	3.31	3.55	3.73	3.86
4¼	5.05	2.52	3.10	3.59	3.98	4.29	4.53	4.71
4½	6.19	2.95	3.65	5.24	4.72	5.11	5.42	5.66
4¾	7.50	3.43	4.26	4.96	5.55	6.03	6.42	6.73
5	9.00	3.95	4.92	5.76	6.46	7.05	7.53	7.92
5¼	10.70	4.51	5.65	6.63	7.46	8.16	8.75	9.23
5½	12.62	5.12	6.43	7.57	8.55	9.38	10.09	10.67
5¾	14.78	5.78	7.28	8.59	9.73	10.71	11.54	12.24
6	17.19	6.49	8.19	9.69	11.00	12.14	13.12	13.95
6¼	19.87	7.25	9.17	10.87	12.37	13.68	14.82	15.80
6½	24.35	7.64	9.77	11.70	13.45	15.02	16.43	17.68
6¾	27.51	8.30	10.64	12.77	14.71	16.47	18.05	19.46
7	30.92	8.99	11.54	13.88	16.02	17.96	19.72	21.31
7¼	34.60	9.70	12.47	15.03	17.37	19.51	21.47	23.24
7½	38.55	10.43	13.43	16.21	18.77	21.12	23.27	25.23
7¾	42.78	11.18	14.42	17.42	20.21	22.77	25.13	27.29
8	47.29	11.95	15.43	18.67	21.68	24.47	27.04	29.41
8¼	52.10	12.74	16.47	19.95	23.20	26.22	29.01	31.60
8½	57.20	13.54	17.53	21.26	24.75	28.01	31.03	33.84
8¾	62.61	14.36	18.61	22.60	26.34	29.84	33.10	36.14
9	68.32	15.20	19.71	23.97	27.97	31.71	35.22	38.49
9¼	74.36	16.05	20.84	25.36	29.62	33.63	37.38	40.90
9½	80.71	16.91	21.98	26.78	31.31	35.57	39.59	43.35
9¾	87.39	17.79	23.14	28.22	33.02	37.56	41.83	45.86
10	94.40	18.68	24.33	29.68	34.76	39.57	44.12	48.40

Cast-iron **16** *feet long.*

if solid, as in the first column, or if hollow, as in the succeed-
the respective headings.

Diameter of Pillar outside.	1¼ Inch.	1⅜ Inch.	1½ Inch.	1⅝ Inch.	1¾ Inch.	1⅞ Inch.	2 Inch.
Inches.							
2							
2¼							
2½							
2¾							
3							
3¼							
3½	2.51						
3¾	3.18	3.21					
4	3.95	4.01	4.05				
4¼	4.84	4.93	4.99	5.02			
4½	5.84	5.97	6.07	6.13	6.16		
4¾	6.97	7.15	7.29	7.38	7.44	7.47	
5	8.23	8.47	8.65	8.78	8.87	8.93	8.97
5¼	9.62	9.93	10.17	10.35	10.49	10.58	10.64
5½	11.16	11.55	11.86	12.10	12.28	12.41	12.50
5¾	12.83	13.31	13.70	14.01	14.25	14.43	14.57
6	14.66	15.24	15.72	16.11	16.42	16.66	16.84
6¼	16.63	17.34	17.92	18.41	18.80	19.11	19.34
6½	18.79	19.76	20.61	21.33	21.95	22.48	22.91
6¾	20.72	21.84	22.82	23.67	24.41	25.04	25.57
7	22.74	24.01	25.13	26.12	26.98	27.73	28.37
7¼	24.83	26.27	27.55	28.68	29.68	30.55	31.31
7½	27.01	28.61	30.06	31.35	32.49	33.51	34.39
7¾	29.26	31.05	32.66	34.12	35.42	36.58	37.60
8	31.58	33.56	35.36	36.99	38.46	39.77	40.94
8¼	33.97	36.15	38.14	39.96	41.60	43.08	44.41
8½	36.43	38.82	41.01	43.01	44.84	46.50	47.99
8¾	38.95	41.56	43.96	46.16	48.18	50.02	51.69
9	41.54	44.36	46.98	49.39	51.61	53.64	55.50
9¼	44.18	47.24	50.08	52.71	55.13	57.37	59.41
9½	46.88	50.17	53.24	56.10	58.74	61.18	63.43
9¾	49.63	53.17	56.48	59.56	62.43	65.09	67.54
10	52.44	56.23	59.78	63.10	66.20	69.08	71.75

Cylindrical Pillars of

Safe weights, in tons of 2,000 pounds, which they can support, ing columns, in which the thickness of the iron is given in

Diameter of Pillar outside.	Solid.	⅜ Inch.	½ Inch.	⅝ Inch.	¾ Inch.	⅞ Inch.	1 Inch.	1⅛ Inch.
Inches.								
2	0.31	0.25	0.29					
2¼	0.48	0.36	0.42	0.45				
2½	0.69	0.50	0.58	0.63	0.67			
2¾	0.97	0.66	0.78	0.86	0.91	0.94		
3	1.32	0.85	1.01	1.13	1.21	1.26	1.30	
3¼	1.76	1.07	1.28	1.44	1.56	1.65	1.70	1.73
3½	2.29	1.32	1.60	1.81	1.97	2.09	2.18	2.23
3¾	2.92	1.60	1.95	2.23	2.45	2.61	2.73	2.81
4	3.68	1.92	2.35	2.70	2.98	3.20	3.36	3.48
4¼	4.56	2.27	2.80	3.24	3.59	3.87	4.08	4.25
4½	5.58	2.66	3.30	3.83	4.26	4.61	4.89	5.11
4¾	6.77	3.09	3.84	4.48	5.01	5.44	5.79	6.07
5	8.12	3.56	4.44	5.19	5.83	6.36	6.79	7.15
5¼	9.65	4.07	5.09	5.98	6.73	7.36	7.89	8.33
5½	11.39	4.62	5.80	6.83	7.71	8.46	9.10	9.63
5¾	13.33	5.21	6.57	7.75	8.77	9.66	10.41	11.04
6	15.51	5.85	7.39	8.74	9.92	10.95	11.83	12.58
6¼	17.93	6.54	8.27	9.81	11.16	12.34	13.37	14.25
6½	20.61	7.27	9.22	10.95	12.49	13.84	15.02	16.05
6¾	23.56	8.05	10.23	12.17	13.91	15.44	16.79	17.97
7	28.51	8.37	10.74	12.90	14.88	16.68	18.31	19.77
7¼	31.93	9.04	11.62	13.99	16.16	18.14	19.95	21.58
7½	35.61	9.73	12.53	15.11	17.48	19.66	21.65	23.46
7¾	39.55	10.45	13.46	16.26	18.84	21.22	23.41	25.41
8	43.76	11.18	14.42	17.45	20.25	22.84	25.23	27.42
8¼	48.25	11.93	15.41	18.66	21.69	24.50	27.10	29.49
8½	53.03	12.69	16.42	19.91	23.17	26.20	29.02	31.62
8¾	58.09	13.48	17.46	21.19	24.69	27.95	30.99	33.81
9	63.45	14.28	18.51	22.50	26.24	29.74	33.01	36.06
9¼	69.12	15.10	19.59	23.83	27.82	31.57	35.07	38.35
9½	75.09	15.93	20.69	25.19	29.44	33.43	37.19	40.70
9¾	81.38	16.77	21.81	26.58	31.08	35.33	39.34	43.10
10	87.98	17.63	22.94	27.98	32.76	37.27	41.53	45.55

Cast-iron **17** *feet long.*

if solid, as in the first column, or if hollow, as in the succeed-
the respective headings.

Diameter of Pillar outside.	1¼ Inch.	1⅜ Inch.	1½ Inch.	1⅝ Inch.	1¾ Inch.	1⅞ Inch.	2 Inch.
Inches.							
2							
2¼							
2½							
2¾							
3							
3¼							
3½	2.26						
3¾	2.86	2.90					
4	3.56	3.62	3.65				
4¼	4.36	4.45	4.50	4.53			
4½	5.27	5.39	5.47	5.53	5.56		
4¾	6.29	6.45	6.57	6.65	6.71	6.74	
5	7.43	7.64	7.80	7.92	8.01	8.06	8.09
5¼	8.68	8.96	9.18	9.34	9.46	9.54	9.59
5½	10.06	10.42	10.69	10.91	11.07	11.19	11.27
5¾	11.57	12.01	12.36	12.64	12.86	13.02	13.14
6	13.22	13.75	14.18	14.54	14.82	15.03	15.19
6¼	15.00	15.64	16.17	16.60	16.95	17.23	17.45
6½	16.93	17.68	18.32	18.85	19.28	19.63	19.91
6¾	19.00	19.88	20.64	21.27	21.80	22.24	22.59
7	21.08	22.24	23.27	24.18	24.97	25.65	26.23
7¼	23.05	24.37	25.54	26.58	27.50	28.29	28.98
7½	25.10	26.58	27.91	29.09	30.14	31.06	31.87
7¾	27.23	28.88	30.37	31.70	32.90	33.96	34.89
8	29.42	31.25	32.91	34.41	35.76	36.97	38.04
8¼	31.69	33.71	35.55	37.22	38.73	40.09	41.31
8½	34.03	36.24	38.27	40.12	41.80	43.33	44.70
8¾	36.43	38.84	41.07	43.11	44.97	46.66	48.20
9	38.89	41.52	43.94	46.18	48.23	50.10	51.81
9¼	41.41	44.26	46.89	49.33	51.58	53.64	55.53
9½	43.99	47.06	49.92	52.57	55.02	57.28	59.36
9¾	46.63	49.93	53.01	55.88	58.54	61.00	63.28
10	49.32	52.85	56.17	59.26	62.14	64.82	67.30

Cylindrical Pillars of

Safe weights, in tons of 2,000 pounds, which they can support, ing columns, in which the thickness of the iron is given in

Diameter of Pillar outside.	Solid.	⅜ Inch.	½ Inch.	⅝ Inch.	¾ Inch.	⅞ Inch.	1 Inch.	1⅛ Inch.
Inches.								
2	0.28	0.23	0.26					
2¼	0.43	0.33	0.38	0.41				
2½	0.63	0.45	0.53	0.58	0.60			
2¾	0.88	0.60	0.70	0.78	0.83	0.86		
3	1.20	0.77	0.92	1.02	1.10	1.15	1.18	
3¼	1.60	0.97	1.16	1.31	1.42	1.49	1.54	1.57
3½	2.08	1.19	1.45	1.64	1.79	1.90	1.97	2.02
3¾	2.65	1.45	1.77	2.02	2.22	2.37	2.48	2.55
4	3.34	1.74	2.13	2.45	2.71	2.90	3.05	3.16
4¼	4.14	2.06	2.54	2.94	3.26	3.51	3.70	3.85
4½	5.07	2.41	2.99	3.47	3.87	4.19	4.44	4.64
4¾	6.14	2.80	3.49	4.06	4.54	4.94	5.26	5.51
5	7.37	3.23	4.03	4.71	5.29	5.77	6.17	6.48
5¼	8.76	3.69	4.62	5.42	6.11	6.68	7.16	7.56
5½	10.33	4.19	5.26	6.20	7.00	7.68	8.26	8.74
5¾	12.10	4.73	5.96	7.03	7.96	8.76	9.45	10.02
6	14.07	5.31	6.71	7.93	9.00	9.94	10.74	11.42
6¼	16.27	5.93	7.51	8.90	10.13	11.20	12.13	12.93
6½	18.70	6.60	8.36	9.94	11.33	12.56	13.63	14.56
6¾	21.38	7.31	9.28	11.05	12.62	14.01	15.24	16.31
7	24.32	8.06	10.25	12.23	13.99	15.56	16.96	18.18
7¼	29.55	8.44	10.84	13.05	15.07	16.91	18.58	20.09
7½	32.98	9.10	11.70	14.11	16.32	18.34	20.19	21.86
7¾	36.66	9.78	12.59	15.20	17.61	19.82	21.85	23.71
8	40.60	10.47	13.51	16.33	18.94	21.35	23.57	25.61
8¼	44.81	11.19	14.45	17.49	20.31	22.93	25.35	27.58
8½	49.28	11.92	15.41	18.68	21.72	24.55	27.18	29.60
8¾	54.03	12.67	16.40	19.90	23.17	26.22	29.06	31.69
9	59.07	13.44	17.41	21.15	24.65	27.93	30.98	33.83
9¼	64.40	14.22	18.44	22.42	26.16	29.67	32.96	36.02
9½	70.02	15.01	19.50	23.73	27.71	31.46	34.97	38.27
9¾	75.94	15.83	20.57	25.06	29.29	33.28	37.04	40.56
10	82.17	16.65	21.66	26.41	30.90	35.14	39.14	42.90

Cast-iron **18** *feet long.*

if solid, as in the first column, or if hollow, as in the succeed-
the respective headings.

Diameter of Pillar outside.	1¼ Inch.	1⅜ Inch.	1½ Inch.	1⅝ Inch.	1¾ Inch.	1⅞ Inch.	2 Inch.
Inches.							
2							
2¼							
2½							
2¾							
3							
3¼							
3½	2.05						
3¾	2.60	2.63					
4	3.23	3.28	3.31				
4¼	3.96	4.03	4.08	4.11			
4½	4.78	4.89	4.97	5.01	5.04		
4¾	5.71	5.86	5.96	6.04	6.09	6.12	
5	6.74	6.93	7.08	7.19	7.26	7.31	7.34
5¼	7.88	8.13	8.33	8.48	8.58	8.66	8.71
5½	9.13	9.45	9.70	9.90	10.05	10.16	10.23
5¾	10.50	10.90	11.22	11.47	11.67	11.81	11.92
6	12.00	12.48	12.87	13.19	13.44	13.64	13.79
6¼	13.61	14.19	14.67	15.07	15.39	15.64	15.83
6½	15.36	16.04	16.62	17.10	17.50	17.82	18.07
6¾	17.24	18.04	18.73	19.30	19.78	20.18	20.50
7	19.26	20.19	20.99	21.67	22.25	22.73	23.12
7¼	21.45	22.66	23.74	24.70	25.54	26.27	26.90
7½	23.38	24.75	25.97	27.06	28.03	28.87	29.61
7¾	25.39	26.92	28.29	29.53	30.62	31.60	32.46
8	27.47	29.17	30.70	32.09	33.33	34.44	35.42
8¼	29.62	31.49	33.20	34.71	36.14	37.39	38.51
8½	31.84	33.89	35.77	37.49	39.04	40.45	41.71
8¾	34.12	36.37	38.43	40.32	42.05	43.61	45.03
9	36.47	38.91	41.17	43.24	45.14	46.88	48.46
9¼	38.87	41.53	43.98	46.25	48.33	50.25	51.99
9½	41.34	44.20	46.86	49.33	51.61	53.71	55.63
9¾	43.86	46.94	49.82	52.49	54.97	57.26	59.37
10	46.44	49.75	52.84	55.73	58.41	60.90	63.21

Cylindrical Pillars of

Safe weights, in tons of 2,000 pounds, which they can support, ing columns, in which the thickness of the iron is given in

Diameter of Pillar outside.	Solid.	⅜ Inch.	½ Inch.	⅝ Inch.	¾ Inch.	⅞ Inch.	1 Inch.	1⅛ Inch.
Inches.								
2	0.26	0.21	0.24					
2¼	0.39	0.30	0.35	0.37				
2½	0.57	0.41	0.48	0.52	0.55			
2¾	0.80	0.54	0.64	0.71	0.76	0.78		
3	1.10	0.70	0.84	0.93	1.00	1.05	1.07	
3¼	1.46	0.88	1.06	1.20	1.29	1.36	1.41	1.43
3½	1.89	1.09	1.32	1.50	1.63	1.73	1.80	1.84
3¾	2.42	1.32	1.61	1.85	2.02	2.16	2.26	2.33
4	3.04	1.59	1.95	2.24	2.47	2.65	2.78	2.88
4¼	3.77	1.88	2.32	2.68	2.97	3.20	3.38	3.51
4½	4.62	2.20	2.73	3.17	3.53	3.82	4.05	4.23
4¾	5.60	2.56	3.18	3.71	4.14	4.50	4.80	5.03
5	6.72	2.95	3.68	4.30	4.83	5.26	5.62	5.91
5¼	7.99	3.37	4.22	4.95	5.57	6.10	6.53	6.89
5½	9.43	3.82	4.80	5.65	6.38	7.01	7.53	7.97
5¾	11.04	4.32	5.44	6.41	7.26	7.99	8.62	9.14
6	12.84	4.85	6.12	7.24	8.21	9.06	9.79	10.42
6¼	14.84	5.41	6.85	8.12	9.24	10.22	11.06	11.80
6½	17.06	6.02	7.63	9.06	10.34	11.45	12.43	13.28
6¾	19.50	6.66	8.46	10.07	11.51	12.78	13.90	14.88
7	22.19	7.35	9.35	11.15	12.76	14.20	15.47	16.59
7¼	25.13	8.08	10.29	12.29	14.09	15.71	17.14	18.41
7½	28.35	8.84	11.29	13.51	15.51	17.31	18.92	20.35
7¾	34.08	9.16	11.80	14.24	16.48	18.55	20.44	22.16
8	37.77	9.83	12.67	15.31	17.75	20.00	22.07	23.97
8¼	41.71	10.51	13.57	16.41	19.05	21.50	23.76	25.83
8½	45.91	11.21	14.49	17.55	20.40	23.04	25.50	27.76
8¾	50.37	11.92	15.43	18.71	21.78	24.63	27.28	29.74
9	55.11	12.66	16.39	19.90	23.19	26.26	29.12	31.78
9¼	60.12	13.41	17.38	21.12	24.64	27.93	31.01	33.88
9½	65.42	14.17	18.39	22.37	26.12	29.64	32.94	36.02
9¾	71.00	14.95	19.42	23.65	27.63	31.39	34.91	38.22
10	76.88	15.75	20.47	24.95	29.18	33.17	36.93	40.46

Cast-iron **19** *feet long.*

if solid, as in the first column, or if hollow, as in the succeed-
the respective headings.

Diameter of Pillar outside.	1¼ Inch.	1⅜ Inch.	1½ Inch.	1⅝ Inch.	1¾ Inch.	1⅞ Inch.	2 Inch.
Inches.							
2							
2¼							
2½							
2¾							
3							
3¼							
3½	1.87						
3¾	2.37	2.40					
4	2.95	2.99	3.02				
4¼	3.61	3.68	3.72	3.75			
4½	4.36	4.46	4.53	4.57	4.60		
4¾	5.21	5.34	5.44	5.51	5.55	5.58	
5	6.15	6.32	6.46	6.56	6.63	6.67	6.70
5¼	7.19	7.42	7.60	7.73	7.83	7.90	7.94
5½	8.33	8.62	8.85	9.03	9.17	9.26	9.33
5¾	9.58	9.94	10.23	10.46	10.64	10.78	10.87
6	10.94	11.38	11.74	12.03	12.26	12.44	12.58
6¼	12.42	12.94	13.38	13.74	14.03	14.26	14.44
6½	14.01	14.64	15.16	15.60	15.96	16.25	16.48
6¾	15.73	16.46	17.08	17.61	18.04	18.40	18.70
7	17.56	18.41	19.14	19.77	20.29	20.73	21.09
7¼	19.53	20.51	21.36	22.09	22.71	23.24	23.68
7½	21.63	22.74	23.72	24.57	25.30	25.93	26.45
7¾	23.73	25.14	26.42	27.56	28.57	29.47	30.26
8	25.70	27.27	28.70	29.98	31.13	32.15	33.06
8¼	27.74	29.48	31.06	32.49	33.78	34.94	35.97
8½	29.84	31.76	33.50	35.09	36.54	37.84	39.00
8¾	32.02	34.11	36.03	37.79	39.39	40.84	42.15
9	34.25	36.53	38.63	40.56	42.33	43.94	45.40
9¼	36.55	39.02	41.31	43.42	45.36	47.14	48.76
9½	38.90	41.58	44.06	46.36	48.48	50.44	52.23
9¾	41.31	44.20	46.88	49.38	51.69	53.82	55.79
10	43.78	46.88	49.78	52.47	54.98	57.30	59.45

Cylindrical Pillars of

Safe weights, in tons of 2,000 pounds, which they can support, ing columns, in which the thickness of the iron is given in

Diameter of Pillar outside.	Solid.	⅜ Inch.	½ Inch.	⅝ Inch.	¾ Inch.	⅞ Inch.	1 Inch.	1⅛ Inch.
Inches.								
2	0.24	0.19	0.22					
2¼	0.36	0.28	0.32	0.34				
2½	0.53	0.38	0.44	0.48	0.51			
2¾	0.74	0.50	0.59	0.65	0.69	0.72		
3	1.00	0.64	0.77	0.86	0.92	0.96	0.98	
3¼	1.33	0.81	0.97	1.10	1.19	1.25	1.29	1.31
3½	1.74	1.00	1.21	1.37	1.50	1.59	1.65	1.69
3¾	2.22	1.21	1.48	1.69	1.86	1.98	2.07	2.13
4	2.79	1.45	1.78	2.05	2.26	2.43	2.55	2.64
4¼	3.46	1.72	2.12	2.45	2.72	2.93	3.10	3.22
4½	4.24	2.02	2.50	2.90	3.23	3.50	3.71	3.88
4¾	5.13	2.34	2.92	3.40	3.80	4.13	4.40	4.61
5	6.16	2.70	3.37	3.94	4.42	4.82	5.15	5.42
5¼	7.32	3.09	3.86	4.53	5.11	5.59	5.99	6.32
5½	8.64	3.51	4.40	5.18	5.85	6.42	6.90	7.30
5¾	10.12	3.96	4.98	5.88	6.66	7.33	7.90	8.38
6	11.77	4.44	5.61	6.63	7.53	8.31	8.98	9.55
6¼	13.60	4.96	6.28	7.44	8.47	9.36	10.14	10.81
6½	15.63	5.52	6.99	8.31	9.47	10.50	11.39	12.17
6¾	17.87	6.11	7.76	9.23	10.55	11.71	12.74	13.64
7	20.34	6.74	8.57	10.22	11.70	13.01	14.18	15.20
7¼	23.03	7.40	9.43	11.27	12.92	14.39	15.71	16.87
7½	25.98	8.11	10.35	12.38	14.21	15.86	17.34	18.66
7¾	29.19	8.85	11.31	13.55	15.59	17.42	19.07	20.55
8	32.67	9.63	12.33	14.80	17.04	19.07	20.90	22.55
8¼	38.92	9.89	12.76	15.43	17.90	20.19	22.30	24.24
8½	42.87	10.55	13.63	16.51	19.18	21.66	23.96	26.08
8¾	47.07	11.24	14.53	17.62	20.50	23.18	25.66	27.96
9	51.53	11.94	15.46	18.76	21.85	24.73	27.42	29.91
9¼	56.25	12.66	16.41	19.93	23.23	26.33	29.22	31.91
9½	61.24	13.39	17.37	21.12	24.65	27.96	31.06	33.96
9¾	66.52	14.14	18.36	22.35	26.10	29.64	32.95	36.06
10	72.07	14.90	19.37	23.59	27.58	31.35	34.88	38.21

Cast-iron **20** *feet long.*

if solid, as in the first column, or if hollow, as in the succeed-
the respective headings.

Diameter of Pillar outside.	1¼ Inch.	1⅜ Inch.	1½ Inch.	1⅝ Inch.	1¾ Inch.	1⅞ Inch.	2 Inch.
Inches.							
2							
2¼							
2½							
2¾							
3							
3¼							
3½	1.72						
3¾	2.17	2.20					
4	2.70	2.74	2.77				
4¼	3.31	3.37	3.41	3.44			
4½	4.00	4.09	4.15	4.19	4.22		
4¾	4.77	4.90	4.99	5.05	5.09	5.11	
5	5.63	5.80	5.92	6.01	6.07	6.11	6.14
5¼	6.59	6.80	6.96	7.09	7.18	7.24	7.28
5½	7.63	7.90	8.11	8.28	8.40	8.49	8.55
5¾	8.78	9.11	9.38	9.59	9.75	9.88	9.97
6	10.03	10.43	10.76	11.03	11.24	11.40	11.53
6¼	11.38	11.86	12.27	12.60	12.86	13.07	13.24
6½	12.84	13.41	13.90	14.30	14.63	14.89	15.11
6¾	14.41	15.08	15.65	16.14	16.54	16.87	17.13
7	16.10	16.88	17.55	18.12	18.60	19.00	19.33
7¼	17.90	18.80	19.57	20.24	20.82	21.30	21.70
7½	19.82	20.85	21.74	22.52	23.19	23.76	24.24
7¾	21.86	23.03	24.05	24.95	25.73	26.40	26.97
8	24.03	25.34	26.51	27.53	28.43	29.21	29.88
8¼	26.02	27.64	29.11	30.44	31.64	32.72	33.67
8½	28.02	29.81	31.43	32.91	34.25	35.46	36.54
8¾	30.09	32.04	33.83	35.47	36.96	38.31	39.53
9	32.22	34.35	36.31	38.11	39.76	41.26	42.62
9¼	34.41	36.72	38.86	40.84	42.65	44.30	45.81
9½	36.66	39.16	41.49	43.64	45.62	47.44	49.11
9¾	38.96	41.67	44.18	46.52	48.68	50.67	52.50
10	41.32	44.23	46.95	49.48	51.82	53.99	56.00

Cylindrical Pillars of

Safe weights, in tons of 2,000 pounds, which they can support, ing columns, in which the thickness of the iron is given in

Diameter of Pillar outside.	Solid.	⅜ Inch.	½ Inch.	⅝ Inch.	¾ Inch.	⅞ Inch.	1 Inch.	1⅛ Inch.
Inches.								
2	0.22	0.18	0.20					
2¼	0.33	0.25	0.29	0.31				
2½	0.48	0.35	0.40	0.44	0.46			
2¾	0.68	0.46	0.54	0.60	0.64	0.66		
3	0.92	0.59	0.71	0.79	0.85	0.88	0.91	
3¼	1.23	0.74	0.89	1.01	1.09	1.15	1.19	1.21
3½	1.60	0.92	1.11	1.26	1.38	1.46	1.52	1.56
3¾	2.04	1.12	1.36	1.56	1.71	1.82	1.90	1.96
4	2.57	1.34	1.64	1.89	2.08	2.23	2.35	2.43
4¼	3.18	1.59	1.96	2.26	2.50	2.70	2.85	2.96
4½	3.90	1.86	2.30	2.67	2.97	3.22	3.42	3.57
4¾	4.72	2.16	2.68	3.13	3.50	3.80	4.05	4.24
5	5.67	2.48	3.10	3.63	4.07	4.44	4.74	4.99
5¼	6.74	2.84	3.56	4.17	4.70	5.14	5.51	5.82
5½	7.95	3.23	4.05	4.77	5.38	5.91	6.35	6.72
5¾	9.31	3.64	4.58	5.41	6.13	6.74	7.27	7.71
6	10.83	4.09	5.16	6.10	6.93	7.64	8.26	8.79
6¼	12.52	4.57	5.78	6.85	7.79	8.62	9.33	9.95
6½	14.39	5.08	6.44	7.65	8.72	9.66	10.49	11.20
6¾	16.45	5.62	7.14	8.50	9.71	10.78	11.72	12.55
7	18.72	6.20	7.89	9.41	10.77	11.98	13.05	13.99
7¼	21.20	6.81	8.68	10.37	11.89	13.25	14.46	15.53
7½	23.91	7.46	9.52	11.39	13.08	14.60	15.96	17.17
7¾	26.86	8.15	10.41	12.48	14.35	16.03	17.55	18.91
8	30.07	8.87	11.35	13.62	15.68	17.55	19.24	20.76
8¼	35.54	9.63	12.34	14.82	17.09	19.15	21.02	22.71
8½	40.12	9.95	12.85	15.56	18.07	20.40	22.55	24.53
8¾	44.07	10.61	13.71	16.62	19.32	21.84	24.17	26.33
9	48.28	11.28	14.60	17.71	20.61	23.32	25.85	28.19
9¼	52.73	11.96	15.50	18.82	21.94	24.85	27.57	30.09
9½	57.45	12.67	16.43	19.97	23.30	26.41	29.33	32.05
9¾	62.43	13.39	17.38	21.14	24.69	28.02	31.14	34.06
10	67.68	14.12	18.35	22.34	26.11	29.66	32.99	36.12

Cast-iron **21** *feet long.*

if solid, as in the first column, or if hollow, as in the succeed-
the respective headings.

Diameter of Pillar outside.	1¼ Inch.	1⅜ Inch.	1½ Inch.	1⅝ Inch.	1¾ Inch.	1⅞ Inch.	2 Inch.
Inches.							
2							
2¼							
2½							
2¾							
3							
3¼							
3½	1.58						
3¾	2.00	2.02					
4	2.49	2.53	2.55				
4¼	3.05	3.10	3.14	3.16			
4½	3.68	3.76	3.82	3.86	3.88		
4¾	4.39	4.51	4.59	4.65	4.68	4.71	
5	5.18	5.34	5.45	5.53	5.59	5.63	5.65
5¼	6.06	6.26	6.41	6.52	6.60	6.66	6.70
5½	7.03	7.27	7.47	7.62	7.73	7.81	7.87
5¾	8.08	8.38	8.63	8.83	8.98	9.09	9.17
6	9.23	9.60	9.90	10.15	10.34	10.50	10.61
6¼	10.48	10.92	11.29	11.59	11.84	12.03	12.18
6½	11.82	12.35	12.79	13.16	13.46	13.71	13.90
6¾	13.27	13.88	14.41	14.85	15.22	15.52	15.77
7	14.82	15.53	16.15	16.68	17.12	17.49	17.79
7¼	16.47	17.30	18.02	18.63	19.16	19.60	19.97
7½	18.24	19.19	20.01	20.73	21.34	21.87	22.31
7¾	20.12	21.19	22.14	22.96	23.68	24.30	24.82
8	22.12	23.33	24.40	25.34	26.17	26.88	27.50
8¼	24.23	25.59	26.80	27.87	28.81	29.64	30.35
8½	26.36	28.02	29.54	30.92	32.17	33.30	34.30
8¾	28.32	30.15	31.83	33.36	34.74	36.00	37.13
9	30.35	32.35	34.19	35.87	37.40	38.80	40.07
9¼	32.44	34.61	36.62	38.46	40.15	41.70	43.11
9½	34.59	36.94	39.12	41.14	42.99	44.69	46.25
9¾	36.79	39.34	41.70	43.89	45.91	47.77	49.48
10	39.06	41.79	44.34	46.71	48.91	50.95	52.82

Cylindrical Pillars of

Safe weights, in tons of 2,000 pounds, which they can support, ing columns, in which the thickness of the iron is given in

Diameter of Pillar outside.	Solid.	⅜ Inch.	½ Inch.	⅝ Inch.	¾ Inch.	⅞ Inch.	1 Inch.	1⅛ Inch.
Inches.								
2	0.20	0.16	0.19					
2¼	0.31	0.23	0.27	0.29				
2½	0.45	0.32	0.37	0.41	0.43			
2¾	0.63	0.42	0.50	0.55	0.59	0.61		
3	0.85	0.55	0.65	0.73	0.78	0.82	0.84	
3¼	1.13	0.69	0.83	0.93	1.01	1.06	1.10	1.12
3½	1.48	0.85	1.03	1.17	1.27	1.35	1.40	1.44
3¾	1.89	1.03	1.26	1.44	1.58	1.68	1.76	1.81
4	2.37	1.24	1.52	1.74	1.92	2.06	2.18	2.25
4¼	2.94	1.46	1.81	2.09	2.31	2.49	2.63	2.74
4½	3.60	1.72	2.13	2.47	2.75	2.98	3.16	3.30
4¾	4.37	1.99	2.48	2.89	3.23	3.51	3.74	3.92
5	5.24	2.30	2.87	3.35	3.76	4.10	4.38	4.61
5¼	6.23	2.62	3.29	3.86	4.34	4.75	5.09	5.37
5½	7.35	2.98	3.74	4.40	4.97	5.46	5.87	6.21
5¾	8.60	3.36	4.24	5.00	5.66	6.23	6.72	7.13
6	10.01	3.78	4.77	5.64	6.40	7.06	7.63	8.12
6¼	11.57	4.22	5.34	6.33	7.20	7.96	8.62	9.19
6½	13.29	4.69	5.95	7.07	8.06	8.93	9.69	10.35
6¾	15.20	5.19	6.60	7.85	8.97	9.96	10.83	11.60
7	17.29	5.73	7.29	8.69	9.95	11.07	12.06	12.93
7¼	19.59	6.29	8.02	9.58	10.99	12.24	13.36	14.35
7½	22.09	6.89	8.80	10.53	12.09	13.49	14.75	15.86
7¾	24.82	7.53	9.62	11.53	13.25	14.82	16.22	17.47
8	27.78	8.19	10.49	12.58	14.49	16.22	17.78	19.18
8¼	30.99	8.90	11.40	13.69	15.79	17.70	19.42	20.98
8½	34.45	9.63	12.36	14.86	17.16	19.25	21.16	22.89
8¾	38.19	10.41	13.37	16.09	18.60	20.89	22.99	24.89
9	45.32	10.67	13.80	16.73	19.47	22.03	24.40	26.60
9¼	49.53	11.32	14.67	17.80	20.74	23.49	26.05	28.43
9½	53.99	12.00	15.56	18.90	22.04	24.98	27.73	30.30
9¾	58.70	12.69	16.46	20.02	23.37	26.52	29.47	32.22
10	63.68	13.39	17.40	21.17	24.74	28.09	31.24	34.20

Cast-iron **22** *feet long.*

if solid, as in the first column, or if hollow, as in the succeed-
the respective headings.

Diameter of Pillar outside.	1¼ Inch.	1⅜ Inch.	1½ Inch.	1⅝ Inch.	1¾ Inch.	1⅞ Inch.	2 Inch.
Inches.							
2							
2¼							
2½							
2¾							
3							
3¼							
3½	1.46						
3¾	1.85	1.87					
4	2.30	2.33	2.35				
4¼	2.82	2.87	2.90	2.92			
4½	3.40	3.48	3.53	3.56	3.59		
4¾	4.06	4.16	4.24	4.29	4.33	4.35	
5	4.79	4.93	5.04	5.11	5.16	5.20	5.22
5¼	5.60	5.78	5.92	6.03	6.10	6.16	6.19
5½	6.49	6.72	6.90	7.04	7.14	7.22	7.27
5¾	7.47	7.75	7.97	8.15	8.29	8.40	8.48
6	8.53	8.87	9.15	9.38	9.56	9.70	9.80
6¼	9.68	10.09	10.43	10.71	10.94	11.12	11.26
6½	10.92	11.41	11.82	12.16	12.44	12.67	12.85
6¾	12.26	12.83	13.31	13.72	14.06	14.34	14.57
7	13.69	14.35	14.92	15.41	15.82	16.16	16.44
7¼	15.22	15.98	16.65	17.22	17.70	18.11	18.45
7½	16.86	17.73	18.49	19.15	19.72	20.21	20.62
7¾	18.59	19.58	20.45	21.22	21.88	22.45	22.93
8	20.44	21.55	22.54	23.42	24.18	24.84	25.41
8¼	22.39	23.64	24.76	25.75	26.62	27.39	28.05
8½	24.45	25.85	27.11	28.22	29.22	30.09	30.85
8¾	26.62	28.18	29.58	30.84	31.96	32.95	33.82
9	28.64	30.51	32.23	33.81	35.25	36.55	37.73
9¼	30.63	32.67	34.55	36.28	37.87	39.31	40.63
9½	32.68	34.90	36.95	38.83	40.57	42.16	43.62
9¾	34.79	37.19	39.41	41.46	43.36	45.11	46.71
10	36.96	39.54	41.94	44.17	46.23	48.14	49.89

Cylindrical Pillars of

Safe weights, in tons of 2,000 pounds, which they can support, ing columns, in which the thickness of the iron is given in

Diameter of Pillar outside.	Solid.	⅜ Inch.	½ Inch.	⅝ Inch.	¾ Inch.	⅞ Inch.	1 Inch.	1⅛ Inch.
Inches.								
2	0.19	0.15	0.17					
2¼	0.29	0.22	0.25	0.27				
2½	0.41	0.30	0.35	0.38	0.40			
2¾	0.58	0.39	0.46	0.51	0.55	0.57		
3	0.79	0.51	0.60	0.67	0.72	0.76	0.78	
3¼	1.05	0.64	0.77	0.86	0.93	0.98	1.02	1.04
3½	1.37	0.79	0.95	1.08	1.18	1.25	1.30	1.33
3¾	1.75	0.96	1.17	1.33	1.46	1.56	1.63	1.68
4	2.20	1.15	1.41	1.62	1.78	1.91	2.01	2.08
4¼	2.73	1.36	1.67	1.93	2.14	2.31	2.44	2.54
4½	3.34	1.59	1.97	2.29	2.55	2.76	2.93	3.06
4¾	4.05	1.85	2.30	2.68	3.00	3.26	3.47	3.63
5	4.86	2.13	2.66	3.11	3.49	3.80	4.06	4.27
5¼	5.77	2.43	3.05	3.58	4.03	4.41	4.72	4.98
5½	6.81	2.76	3.47	4.08	4.61	5.06	5.44	5.76
5¾	7.98	3.12	3.93	4.63	5.25	5.78	6.23	6.61
6	9.28	3.50	4.42	5.23	5.94	6.55	7.08	7.53
6¼	10.72	3.91	4.95	5.87	6.68	7.38	8.00	8.52
6½	12.33	4.35	5.51	6.55	7.47	8.28	8.98	9.60
6¾	14.09	4.82	6.12	7.28	8.32	9.24	10.04	10.75
7	16.03	5.31	6.76	8.06	9.22	10.26	11.18	11.99
7¼	18.16	5.84	7.44	8.88	10.19	11.35	12.39	13.31
7½	20.49	6.39	8.16	9.76	11.21	12.51	13.67	14.71
7¾	23.01	6.98	8.92	10.69	12.29	13.74	15.04	16.20
8	25.76	7.60	9.72	11.67	13.43	15.03	16.48	17.78
8¼	28.73	8.25	10.57	12.70	14.64	16.41	18.01	19.46
8½	31.95	8.93	11.46	13.78	15.91	17.85	19.62	21.22
8¾	35.41	9.65	12.39	14.92	17.25	19.37	21.31	23.08
9	39.13	10.40	13.37	16.12	18.65	20.97	23.10	25.04
9¼	46.61	10.73	13.89	16.86	19.64	22.23	24.64	26.89
9½	50.83	11.38	14.75	17.91	20.88	23.66	26.26	28.68
9¾	55.30	12.04	15.62	18.99	22.16	25.13	27.92	30.52
10	60.01	12.72	16.51	20.09	23.47	26.64	29.62	32.41

Cast-iron **23** *feet long.*

if solid, as in the first column, or if hollow, as in the succeed-
the respective headings.

Diameter of Pillar outside. Inches.	1¼ Inch.	1⅜ Inch.	1½ Inch.	1⅝ Inch.	1¾ Inch.	1⅞ Inch.	2 Inch.
2							
2¼							
2½							
2¾							
3							
3¼							
3½	1.35						
3¾	1.71	1.73					
4	2.13	2.16	2.18				
4¼	2.61	2.66	2.69	2.71			
4½	3.15	3.22	3.27	3.31	3.32		
4¾	3.76	3.86	3.93	3.98	4.01	4.03	
5	4.44	4.57	4.67	4.74	4.79	4.82	4.84
5¼	5.19	5.36	5.49	5.59	5.66	5.71	5.74
5½	6.02	6.23	6.40	6.53	6.62	6.69	6.74
5¾	6.92	7.18	7.39	7.56	7.69	7.79	7.86
6	7.91	8.22	8.48	8.69	8.86	8.99	9.09
6¼	8.97	9.35	9.67	9.93	10.14	10.31	10.44
6½	10.13	10.58	10.96	11.27	11.53	11.74	11.91
6¾	11.37	11.89	12.34	12.72	13.04	13.30	13.51
7	12.69	13.31	13.84	14.29	14.67	14.98	15.24
7¼	14.11	14.82	15.43	15.96	16.41	16.79	17.11
7½	15.63	16.44	17.14	17.76	18.29	18.74	19.12
7¾	17.24	18.16	18.97	19.67	20.29	20.81	21.26
8	18.95	19.98	20.90	21.71	22.42	23.03	23.56
8¼	20.76	21.92	22.96	23.88	24.68	25.39	26.01
8½	22.67	23.97	25.13	26.17	27.09	27.90	28.60
8¾	24.68	26.13	27.43	28.60	29.63	30.55	31.36
9	26.81	28.41	29.85	31.16	32.32	33.36	34.28
9¼	28.96	30.88	32.65	34.28	35.76	37.12	38.35
9½	30.93	33.01	34.94	36.71	38.34	39.84	41.20
9¾	32.94	35.20	37.29	39.22	41.01	42.65	44.15
10	35.02	37.45	39.71	41.81	43.75	45.54	47.19

Cylindrical Pillars of

Safe weights, in tons of 2,000 pounds, which they can support,
ing columns, in which the thickness of the iron is given in

Diameter of Pillar outside.	Solid.	⅜ Inch.	½ Inch.	⅝ Inch.	¾ Inch.	⅞ Inch.	1 Inch.	1⅛ Inch.
Inches.								
2	0.17	0.14	0.16					
2¼	0.26	0.20	0.23	0.25				
2½	0.39	0.28	0.32	0.35	0.37			
2¾	0.54	0.37	0.43	0.48	0.51	0.53		
3	0.74	0.47	0.56	0.63	0.67	0.70	0.72	
3¼	0.98	0.59	0.71	0.80	0.87	0.92	0.95	0.96
3½	1.27	0.73	0.89	1.01	1.10	1.16	1.21	1.24
3¾	1.63	0.89	1.09	1.24	1.36	1.45	1.52	1.56
4	2.05	1.07	1.31	1.50	1.66	1.78	1.87	1.94
4¼	2.54	1.26	1.56	1.80	2.00	2.15	2.27	2.36
4½	3.11	1.48	1.83	2.13	2.37	2.57	2.72	2.84
4¾	3.76	1.72	2.14	2.49	2.79	3.03	3.22	3.38
5	4.52	1.98	2.47	2.89	3.24	3.54	3.78	3.98
5¼	5.37	2.26	2.83	3.33	3.74	4.10	4.39	4.63
5½	6.34	2.57	3.23	3.80	4.29	4.71	5.06	5.36
5¾	7.42	2.90	3.65	4.31	4.88	5.37	5.79	6.15
6	8.63	3.26	4.11	4.86	5.52	6.09	6.58	7.00
6¼	9.97	3.64	4.60	5.46	6.21	6.87	7.44	7.93
6½	11.47	4.05	5.13	6.09	6.95	7.70	8.36	8.93
6¾	13.11	4.48	5.69	6.77	7.74	8.59	9.34	10.00
7	14.92	4.94	6.29	7.50	8.58	9.54	10.40	11.15
7¼	16.89	5.43	6.92	8.27	9.48	10.56	11.52	12.38
7½	19.05	5.95	7.59	9.08	10.43	11.64	12.72	13.68
7¾	21.41	6.49	8.30	9.94	11.43	12.78	13.99	15.07
8	23.96	7.07	9.05	10.85	12.50	13.99	15.33	16.54
8¼	26.73	7.67	9.83	11.81	13.62	15.26	16.75	18.10
8½	29.72	8.31	10.66	12.82	14.80	16.61	18.25	19.74
8¾	32.94	8.97	11.53	13.88	16.04	18.02	19.83	21.47
9	36.40	9.67	12.44	14.99	17.35	19.51	21.48	23.29
9¼	40.12	10.40	13.39	16.16	18.71	21.06	23.22	25.20
9½	44.10	11.17	14.39	17.37	20.14	22.69	25.05	27.21
9¾	52.18	11.44	14.83	18.03	21.03	23.85	26.48	28.94
10	56.65	12.09	15.69	19.09	22.29	25.29	28.11	30.75

Cast-iron **24** *feet long.*

if solid, as in the first column, or if hollow, as in the succeed-
the respective headings.

Diameter of Pillar outside.	1¼ Inch.	1⅜ Inch.	1½ Inch.	1⅝ Inch.	1¾ Inch.	1⅞ Inch.	2 Inch.
Inches.							
2							
2¼							
2½							
2¾							
3							
3¼							
3½	1.26						
3¾	1.59	1.61					
4	1.98	2.01	2.03				
4¼	2.43	2.47	2.50	2.52			
4½	2.93	3.00	3.04	3.07	3.09		
4¾	3.50	3.59	3.66	3.70	3.73	3.75	
5	4.13	4.25	4.34	4.41	4.45	4.48	4.50
5¼	4.83	4.99	5.11	5.20	5.26	5.31	5.34
5½	5.60	5.79	5.95	6.07	6.16	6.23	6.27
5¾	6.44	6.68	6.88	7.03	7.15	7.24	7.31
6	7.36	7.65	7.89	8.09	8.24	8.36	8.45
6¼	8.35	8.70	9.00	9.24	9.43	9.59	9.71
6½	9.42	9.84	10.19	10.49	10.73	10.92	11.08
6¾	10.57	11.06	11.48	11.84	12.13	12.37	12.57
7	11.81	12.38	12.87	13.29	13.64	13.94	14.18
7¼	13.13	13.79	14.36	14.85	15.27	15.62	15.92
7½	14.54	15.29	15.95	16.52	17.01	17.43	17.78
7¾	16.04	16.89	17.64	18.30	18.97	19.36	19.78
8	17.63	18.59	19.44	20.20	20.85	21.42	21.92
8¼	19.31	20.39	21.36	22.21	22.96	23.62	24.19
8½	21.09	22.30	23.38	24.34	25.20	25.95	26.61
8¾	22.96	24.31	25.52	26.60	27.56	28.42	29.17
9	24.93	26.43	27.77	28.98	30.06	31.03	31.88
9¼	27.01	28.65	30.14	31.49	32.70	33.78	34.75
9½	29.19	30.99	32.64	34.13	35.47	36.68	37.77
9¾	31.23	33.36	35.33	37.15	38.84	40.38	41.79
10	33.22	35.51	37.65	39.63	41.46	43.15	44.70

Cylindrical Pillars of

Safe weights, in tons of 2,000 pounds, which they can support, ing columns, in which the thickness of the iron is given in

Diameter of Pillar outside.	Solid.	⅜ Inch.	½ Inch.	⅝ Inch.	¾ Inch.	⅞ Inch.	1 Inch.	1⅛ Inch.
Inches.								
2	0.16	0.13	0.15					
2¼	0.25	0.19	0.22	0.23				
2½	0.36	0.26	0.30	0.33	0.35			
2¾	0.50	0.34	0.40	0.45	0.47	0.49		
3	0.69	0.44	0.52	0.59	0.63	0.66	0.67	
3¼	0.91	0.55	0.66	0.75	0.81	0.85	0.88	0.90
3½	1.19	0.68	0.83	0.94	1.02	1.09	1.13	1.16
3¾	1.52	0.83	1.01	1.16	1.27	1.35	1.42	1.46
4	1.91	1.00	1.22	1.40	1.55	1.66	1.75	1.81
4¼	2.37	1.18	1.45	1.68	1.86	2.01	2.12	2.20
4½	2.90	1.38	1.71	1.99	2.21	2.39	2.54	2.65
4¾	3.51	1.60	1.99	2.32	2.60	2.83	3.01	3.15
5	4.21	1.85	2.31	2.70	3.03	3.30	3.53	3.71
5¼	5.01	2.11	2.64	3.10	3.49	3.82	4.10	4.32
5½	5.91	2.40	3.01	3.54	4.00	4.39	4.72	5.00
5¾	6.92	2.71	3.41	4.02	4.55	5.01	5.40	5.73
6	8.05	3.04	3.84	4.54	5.15	5.68	6.14	6.53
6¼	9.31	3.39	4.29	5.09	5.79	6.41	6.94	7.40
6½	10.70	3.77	4.79	5.68	6.48	7.18	7.80	8.33
6¾	12.23	4.18	5.31	6.32	7.22	8.01	8.72	9.33
7	13.92	4.61	5.86	6.99	8.00	8.90	9.70	10.40
7¼	15.76	5.06	6.46	7.71	8.84	9.85	10.75	11.55
7½	17.78	5.55	7.08	8.47	9.73	10.86	11.87	12.77
7¾	19.97	6.06	7.74	9.27	10.67	11.92	13.05	14.06
8	22.36	6.59	8.44	10.13	11.66	13.05	14.30	15.43
8¼	24.94	7.16	9.17	11.02	12.71	14.24	15.63	16.88
8½	27.72	7.75	9.94	11.96	13.81	15.49	17.03	18.42
8¾	30.73	8.37	10.76	12.95	14.97	16.81	18.50	20.03
9	33.96	9.02	11.60	13.99	16.18	18.20	20.04	21.73
9¼	37.43	9.71	12.49	15.07	17.46	19.65	21.67	23.51
9½	41.15	10.42	13.42	16.21	18.79	21.17	23.37	25.38
9¾	45.12	11.16	14.39	17.40	20.18	22.77	25.15	27.34
10	49.36	11.93	15.40	18.64	21.64	24.43	27.01	29.39

Cast-iron **25** *feet long.*

if solid, as in the first column, or if hollow, as in the succeed-
the respective headings.

Diameter of Pillar outside.	1¼ Inch.	1⅜ Inch.	1½ Inch.	1⅝ Inch.	1¾ Inch.	1⅞ Inch.	2 Inch.
Inches.							
2							
2¼							
2½							
2¾							
3							
3¼							
3½	1.17						
3¾	1.49	1.50					
4	1.85	1.88	1.89				
4¼	2.27	2.31	2.34	2.35			
4½	2.74	2.80	2.84	2.87	2.88		
4¾	3.26	3.35	3.41	3.45	3.48	3.50	
5	3.85	3.97	4.05	4.11	4.16	4.18	4.20
5¼	4.51	4.65	4.76	4.85	4.91	4.95	4.98
5½	5.22	5.41	5.55	5.66	5.75	5.81	5.85
5¾	6.01	6.23	6.42	6.56	6.67	6.76	6.82
6	6.86	7.14	7.36	7.55	7.69	7.80	7.89
6¼	7.79	8.12	8.39	8.62	8.80	8.95	9.06
6½	8.79	9.18	9.51	9.78	10.01	10.19	10.34
6¾	9.86	10.32	10.71	11.04	11.32	11.54	11.72
7	11.02	11.55	12.01	12.40	12.73	13.00	13.23
7¼	12.25	12.86	13.39	13.85	14.24	14.57	14.85
7½	13.56	14.26	14.88	15.41	15.87	16.26	16.59
7¾	14.96	15.76	16.46	17.07	17.60	18.06	18.45
8	16.44	17.34	18.14	18.84	19.46	19.99	20.45
8¼	18.01	19.02	19.92	20.72	21.42	22.04	22.57
8½	19.67	20.80	21.81	22.71	23.51	24.21	24.82
8¾	21.42	22.68	23.81	24.82	25.72	26.51	27.21
9	23.26	24.65	25.91	27.04	28.05	28.95	29.74
9¼	25.20	26.73	28.12	29.38	30.51	31.52	32.42
9½	27.23	28.92	30.45	31.84	33.09	34.22	35.23
9¾	29.36	31.20	32.89	34.42	35.81	37.07	38.20
10	31.39	33.60	35.45	37.13	38.67	40.06	41.31

Cylindrical Pillars of

Safe weights, in tons of 2,000 pounds, which they can support,
ing columns, in which the thickness of the iron is given in

Diameter of Pillar outside.	Solid.	⅜ Inch.	½ Inch.	⅝ Inch.	¾ Inch.	⅞ Inch.	1 Inch.	1⅛ Inch.
Inches.								
2	0.15	0.12	0.14					
2¼	0.23	0.18	0.20	0.22				
2½	0.34	0.24	0.28	0.31	0.32			
2¾	0.47	0.32	0.38	0.42	0.44	0.46		
3	0.64	0.41	0.49	0.55	0.59	0.61	0.63	
3¼	0.85	0.52	0.62	0.70	0.76	0.80	0.82	0.84
3½	1.11	0.64	0.77	0.88	0.96	1.02	1.06	1.08
3¾	1.42	0.78	0.95	1.08	1.19	1.27	1.32	1.36
4	1.79	0.93	1.14	1.31	1.45	1.55	1.63	1.69
4¼	2.21	1.10	1.36	1.57	1.74	1.88	1.98	2.06
4½	2.71	1.29	1.60	1.86	2.07	2.24	2.37	2.48
4¾	3.29	1.50	1.87	2.17	2.43	2.64	2.81	2.95
5	3.94	1.73	2.16	2.52	2.83	3.09	3.30	3.47
5¼	4.69	1.98	2.47	2.90	3.27	3.58	3.83	4.04
5½	5.53	2.24	2.82	3.32	3.74	4.11	4.42	4.68
5¾	6.48	2.53	3.19	3.76	4.26	4.69	5.05	5.36
6	7.53	2.84	3.59	4.25	4.82	5.32	5.75	6.11
6¼	8.71	3.18	4.02	4.76	5.42	5.99	6.49	6.92
6½	10.01	3.53	4.48	5.32	6.06	6.72	7.29	7.79
6¾	11.44	3.91	4.97	5.91	6.75	7.50	8.15	8.73
7	13.02	4.31	5.49	6.54	7.49	8.33	9.07	9.73
7¼	14.75	4.74	6.04	7.21	8.27	9.21	10.06	10.80
7½	16.63	5.19	6.62	7.92	9.10	10.16	11.10	11.94
7¾	18.68	5.67	7.24	8.68	9.98	11.15	12.21	13.15
8	20.91	6.17	7.89	9.47	10.91	12.21	13.38	14.44
8¼	23.33	6.70	8.58	10.31	11.89	13.32	14.62	15.79
8½	25.94	7.25	9.30	11.19	12.92	14.49	15.93	17.23
8¾	28.75	7.83	10.06	12.11	14.00	15.73	17.30	18.74
9	31.77	8.44	10.86	13.09	15.14	17.02	18.75	20.33
9¼	35.02	9.08	11.69	14.10	16.33	18.38	20.27	22.00
9½	38.49	9.75	12.56	15.16	17.58	19.81	21.86	23.75
9¾	42.21	10.44	13.46	16.27	18.88	21.30	23.53	25.58
10	46.18	11.16	14.41	17.43	20.24	22.85	25.27	27.50

Cast-iron **26** *feet long.*

if solid, as in the first column, or if hollow, as in the succeed-
the respective headings.

Diameter of Pillar outside.	1¼ Inch.	1⅜ Inch.	1½ Inch.	1⅝ Inch.	1¾ Inch.	1⅞ Inch.	2 Inch.
Inches.							
2							
2¼							
2½							
2¾							
3							
3¼							
3½	1.10						
3¾	1.39	1.41					
4	1.73	1.76	1.77				
4¼	2.12	2.16	2.18	2.20			
4½	2.56	2.62	2.66	2.68	2.70		
4¾	3.05	3.13	3.19	3.23	3.26	3.27	
5	3.61	3.71	3.79	3.85	3.89	3.91	3.93
5¼	4.22	4.35	4.46	4.54	4.59	4.63	4.66
5½	4.89	5.06	5.19	5.30	5.38	5.43	5.47
5¾	5.62	5.83	6.00	6.14	6.24	6.32	6.38
6	6.42	6.68	6.89	7.06	7.19	7.30	7.38
6¼	7.29	7.59	7.85	8.06	8.23	8.37	8.47
6½	8.22	8.59	8.90	9.15	9.36	9.53	9.67
6¾	9.23	9.65	10.02	10.33	10.59	10.80	10.97
7	10.31	10.80	11.23	11.60	11.91	12.16	12.37
7¼	11.46	12.03	12.53	12.96	13.32	13.63	13.89
7½	12.69	13.34	13.92	14.42	14.84	15.21	15.52
7¾	14.00	14.74	15.40	15.97	16.47	16.90	17.26
8	15.38	16.22	16.97	17.63	18.20	18.70	19.13
8¼	16.85	17.80	18.64	19.38	20.04	20.61	21.11
8½	18.40	19.46	20.40	21.25	21.99	22.65	23.22
8¾	20.04	21.21	22.27	23.22	24.06	24.80	25.46
9	21.76	23.06	24.24	25.29	26.24	27.08	27.83
9¼	23.57	25.01	26.31	27.48	28.54	29.48	30.33
9½	25.47	27.05	28.48	29.79	30.96	32.02	32.96
9¾	27.46	29.19	30.77	32.20	33.50	34.68	35.73
10	29.55	31.43	33.16	34.74	36.17	37.47	38.65

Cylindrical Pillars of

Safe weights, in tons of 2,000 pounds, which they can support, ing columns, in which the thickness of the iron is given in

Diameter of Pillar outside. Inches.	Solid.	⅜ Inch.	½ Inch.	⅝ Inch.	¾ Inch.	⅞ Inch.	1 Inch.	1⅛ Inch.
2	0.14	0.12	0.13					
2¼	0.22	0.17	0.19	0.20				
2½	0.32	0.23	0.26	0.29	0.30			
2¾	0.44	0.30	0.35	0.39	0.42	0.43		
3	0.60	0.39	0.46	0.51	0.55	0.58	0.59	
3¼	0.80	0.48	0.58	0.66	0.71	0.75	0.77	0.79
3½	1.04	0.60	0.73	0.82	0.90	0.95	0.99	1.01
3¾	1.33	0.73	0.89	1.02	1.11	1.19	1.24	1.28
4	1.67	0.87	1.07	1.23	1.36	1.46	1.53	1.59
4¼	2.08	1.03	1.28	1.47	1.63	1.76	1.86	1.93
4½	2.54	1.21	1.50	1.74	1.94	2.10	2.23	2.33
4¾	3.08	1.41	1.75	2.04	2.28	2.48	2.64	2.77
5	3.70	1.62	2.02	2.37	2.66	2.90	3.09	3.25
5¼	4.40	1.85	2.32	2.72	3.06	3.35	3.60	3.79
5½	5.19	2.10	2.64	3.11	3.51	3.85	4.14	4.39
5¾	6.07	2.37	2.99	3.53	4.00	4.40	4.74	5.03
6	7.06	2.67	3.37	3.98	4.52	4.99	5.39	5.73
6¼	8.17	2.98	3.77	4.47	5.08	5.62	6.09	6.49
6½	9.38	3.31	4.20	4.99	5.69	6.30	6.84	7.31
6¾	10.73	3.67	4.66	5.54	6.33	7.03	7.65	8.19
7	12.21	4.04	5.14	6.14	7.02	7.81	8.51	9.13
7¼	13.83	4.44	5.66	6.76	7.76	8.64	9.43	10.13
7½	15.60	4.87	6.21	7.43	8.53	9.52	10.41	11.20
7¾	17.52	5.31	6.79	8.14	9.36	10.46	11.45	12.34
8	19.61	5.78	7.40	8.88	10.23	11.45	12.55	13.54
8¼	21.88	6.28	8.05	9.67	11.15	12.49	13.71	14.81
8½	24.32	6.80	8.72	10.49	12.11	13.59	14.94	16.16
8¾	26.96	7.35	9.44	11.36	13.13	14.75	16.23	17.57
9	29.80	7.92	10.18	12.27	14.20	15.97	17.59	19.06
9¼	32.84	8.52	10.96	13.22	15.32	17.24	19.01	20.63
9½	36.10	9.14	11.78	14.22	16.49	18.58	20.50	22.27
9¾	39.59	9.79	12.63	15.26	17.71	19.97	22.06	23.99
10	43.31	10.47	13.51	16.35	18.99	21.43	23.70	25.79

Cast-iron **27** *feet long.*

if solid, as in the first column, or if hollow, as in the succeed-
the respective headings.

Diameter of Pillar outside.	1¼ Inch.	1⅜ Inch.	1½ Inch.	1⅝ Inch.	1¾ Inch.	1⅞ Inch.	2 Inch.
Inches.							
2							
2¼							
2½							
2¾							
3							
3¼							
3½	1.03						
3¾	1.30	1.32					
4	1.62	1.65	1.66				
4¼	1.99	2.03	2.05	2.06			
4½	2.40	2.45	2.49	2.52	2.53		
4¾	2.86	2.94	2.99	3.03	3.05	3.07	
5	3.38	3.48	3.55	3.61	3.65	3.67	3.69
5¼	3.95	4.08	4.18	4.25	4.31	4.35	4.37
5½	4.58	4.74	4.87	4.97	5.04	5.10	5.14
5¾	5.27	5.47	5.63	5.76	5.86	5.93	5.98
6	6.02	6.26	6.46	6.62	6.75	6.85	6.92
6¼	6.83	7.12	7.36	7.56	7.72	7.85	7.95
6½	7.71	8.05	8.34	8.58	8.78	8.94	9.07
6¾	8.65	9.05	9.40	9.69	9.93	10.13	10.29
7	9.66	10.13	10.53	10.88	11.17	11.41	11.61
7¼	10.75	11.28	11.75	12.15	12.50	12.79	13.03
7½	11.90	12.52	13.05	13.52	13.92	14.27	14.56
7¾	13.13	13.82	14.44	14.98	15.45	15.85	16.19
8	14.43	15.22	15.92	16.53	17.07	17.54	17.94
8¼	15.80	16.69	17.48	18.18	18.80	19.33	19.80
8½	17.26	18.25	19.14	19.93	20.62	21.24	21.78
8¾	18.79	19.90	20.89	21.77	22.56	23.26	23.88
9	20.41	21.63	22.73	23.72	24.61	25.40	26.10
9¼	22.11	23.45	24.67	25.77	26.77	27.65	28.44
9½	23.89	25.37	26.71	27.93	29.04	30.03	30.91
9¾	25.76	27.38	28.86	30.20	31.42	32.52	33.51
10	27.71	29.48	31.10	32.58	33.92	35.14	36.25

Cylindrical Pillars of

Safe weights, in tons of 2,000 pounds, which they can support, ing columns, in which the thickness of the iron is given in

Diameter of Pillar outside.	Solid.	⅜ Inch.	½ Inch.	⅝ Inch.	¾ Inch.	⅞ Inch.	1 Inch.	1⅛ Inch.
Inches.								
2	0.13	0.11	0.12					
2¼	0.20	0.16	0.18	0.19				
2½	0.30	0.21	0.25	0.27	0.29			
2¾	0.42	0.28	0.33	0.37	0.39	0.40		
3	0.57	0.36	0.43	0.48	0.52	0.54	0.56	
3¼	0.75	0.46	0.55	0.62	0.67	0.70	0.73	0.74
3½	0.98	0.56	0.68	0.78	0.85	0.90	0.93	0.95
3¾	1.25	0.68	0.84	0.95	1.05	1.12	1.17	1.20
4	1.57	0.82	1.01	1.16	1.28	1.37	1.44	1.49
4¼	1.95	0.97	1.20	1.38	1.54	1.65	1.75	1.82
4½	2.39	1.14	1.41	1.64	1.82	1.97	2.09	2.19
4¾	2.90	1.32	1.64	1.92	2.14	2.33	2.48	2.60
5	3.48	1.52	1.90	2.22	2.50	2.72	2.91	3.06
5¼	4.13	1.74	2.18	2.56	2.88	3.15	3.38	3.57
5½	4.88	1.98	2.48	2.92	3.30	3.62	3.90	4.12
5¾	5.71	2.23	2.81	3.32	3.76	4.13	4.46	4.73
6	6.64	2.51	3.16	3.74	4.25	4.69	5.07	5.39
6¼	7.68	2.80	3.54	4.20	4.78	5.28	5.72	6.10
6½	8.82	3.11	3.95	4.69	5.35	5.92	6.43	6.87
6¾	10.09	3.45	4.38	5.21	5.95	6.61	7.19	7.70
7	11.48	3.80	4.84	5.77	6.60	7.34	8.00	8.58
7¼	13.00	4.18	5.32	6.36	7.29	8.12	8.87	9.52
7½	14.66	4.57	5.84	6.99	8.02	8.95	9.79	10.53
7¾	16.47	4.99	6.38	7.65	8.80	9.83	10.76	11.60
8	18.44	5.44	6.96	8.35	9.62	10.76	11.80	12.73
8¼	20.57	5.90	7.57	9.09	10.48	11.74	12.89	13.93
8½	22.87	6.39	8.20	9.86	11.39	12.78	14.04	15.19
8¾	25.34	6.91	8.87	10.68	12.34	13.87	15.26	16.52
9	28.01	7.44	9.57	11.54	13.35	15.01	16.53	17.92
9¼	30.87	8.00	10.30	12.43	14.40	16.21	17.87	19.39
9½	33.94	8.59	11.07	13.37	15.50	17.46	19.27	20.94
9¾	37.21	9.20	11.87	14.35	16.65	18.78	20.74	22.55
10	40.71	9.84	12.70	15.37	17.85	20.15	22.27	24.24

Cast-iron **28** *feet long.*

if solid, as in the first column, or if hollow, as in the succeed- the respective headings.

Diameter of Pillar outside.	1¼ Inch.	1⅜ Inch.	1½ Inch.	1⅝ Inch.	1¾ Inch.	1⅞ Inch.	2 Inch.
Inches.							
2							
2¼							
2½							
2¾							
3							
3¼							
3½	0.97						
3¾	1.23	1.24					
4	1.53	1.55	1.56				
4¼	1.87	1.90	1.93	1.94			
4½	2.26	2.31	2.34	2.37	2.38		
4¾	2.69	2.76	2.81	2.85	2.87	2.89	
5	3.18	3.27	3.34	3.39	3.43	3.45	3.46
5¼	3.72	3.84	3.93	4.00	4.05	4.08	4.11
5½	4.31	4.46	4.58	4.67	4.74	4.79	4.83
5¾	4.96	5.14	5.29	5.41	5.50	5.57	5.62
6	5.66	5.89	6.07	6.22	6.34	6.44	6.51
6¼	6.42	6.70	6.92	7.11	7.26	7.38	7.47
6½	7.25	7.57	7.84	8.07	8.25	8.41	8.52
6¾	8.13	8.51	8.83	9.11	9.33	9.52	9.67
7	9.09	9.52	9.90	10.22	10.50	10.72	10.91
7¼	10.10	10.61	11.05	11.43	11.75	12.02	12.25
7½	11.19	11.76	12.27	12.71	13.09	13.41	13.68
7¾	12.34	13.00	13.57	14.08	14.52	14.90	15.22
8	13.56	14.30	14.96	15.54	16.05	16.49	16.86
8¼	14.86	15.69	16.43	17.09	17.67	18.17	18.61
8½	16.22	17.16	17.99	18.73	19.39	19.97	20.47
8¾	17.67	18.70	19.63	20.47	21.21	21.87	22.45
9	19.19	20.33	21.37	22.30	23.13	23.88	24.53
9¼	20.78	22.05	23.19	24.23	25.16	25.99	26.74
9½	22.46	23.85	25.11	26.26	27.30	28.23	29.06
9¾	24.21	25.74	27.13	28.39	29.54	30.57	31.50
10	26.05	27.71	29.24	30.63	31.89	33.04	34.07

Cylindrical Pillars of

Safe weights, in tons of 2,000 pounds, which they can support, ing columns, in which the thickness of the iron is given in

Diameter of Pillar outside.	Solid.	⅜ Inch.	½ Inch.	⅝ Inch.	¾ Inch.	⅞ Inch.	1 Inch.	1⅛ Inch.
Inches.								
2	0.13	0.10	0.12					
2¼	0.19	0.15	0.17	0.18				
2½	0.28	0.20	0.23	0.26	0.27			
2¾	0.39	0.26	0.31	0.35	0.37	0.38		
3	0.53	0.34	0.41	0.45	0.49	0.51	0.52	
3¼	0.71	0.43	0.52	0.58	0.63	0.66	0.69	0.70
3½	0.92	0.53	0.64	0.73	0.80	0.84	0.88	0.90
3¾	1.18	0.64	0.79	0.90	0.99	1.05	1.10	1.13
4	1.48	0.77	0.95	1.09	1.20	1.29	1.36	1.40
4¼	1.84	0.92	1.13	1.30	1.45	1.56	1.65	1.71
4½	2.25	1.07	1.33	1.54	1.72	1.86	1.97	2.06
4¾	2.73	1.25	1.55	1.81	2.02	2.20	2.34	2.45
5	3.27	1.44	1.79	2.10	2.35	2.56	2.74	2.88
5¼	3.89	1.64	2.05	2.41	2.71	2.97	3.18	3.36
5½	4.59	1.86	2.34	2.75	3.11	3.41	3.67	3.88
5¾	5.38	2.10	2.65	3.12	3.54	3.89	4.20	4.45
6	6.26	2.36	2.98	3.53	4.00	4.42	4.77	5.08
6¼	7.23	2.64	3.34	3.96	4.50	4.98	5.39	5.75
6½	8.31	2.93	3.72	4.42	5.04	5.58	6.06	6.47
6¾	9.50	3.25	4.12	4.91	5.61	6.23	6.77	7.25
7	10.81	3.58	4.56	5.43	6.22	6.92	7.54	8.08
7¼	12.25	3.94	5.02	5.99	6.87	7.65	8.35	8.97
7½	13.81	4.31	5.50	6.58	7.56	8.43	9.22	9.92
7¾	15.52	4.71	6.02	7.21	8.29	9.26	10.14	10.93
8	17.37	5.12	6.56	7.87	9.06	10.14	11.11	11.99
8¼	19.37	5.56	7.13	8.56	9.87	11.06	12.14	13.12
8½	21.54	6.02	7.73	9.29	10.73	12.04	13.23	14.31
8¾	23.88	6.51	8.36	10.06	11.63	13.06	14.37	15.56
9	26.39	7.01	9.02	10.87	12.57	14.14	15.57	16.88
9¼	29.08	7.54	9.71	11.71	13.56	15.27	16.84	18.27
9½	31.97	8.09	10.43	12.59	14.60	16.45	18.16	19.72
9¾	35.06	8.67	11.18	13.52	15.68	17.69	19.54	21.25
10	38.36	9.27	11.97	14.48	16.81	18.98	20.99	22.84

Cast iron **29** *feet long.*

if solid, as in the first column, or if hollow, as in the succeed-
the respective headings.

Diameter of Pillar outside.	1¼ Inch.	1⅜ Inch.	1½ Inch.	1⅝ Inch.	1¾ Inch.	1⅞ Inch.	2 Inch.
Inches.							
2							
2¼							
2½							
2¾							
3							
3¼							
3½	0.91						
3¾	1.15	1.17					
4	1.44	1.46	1.47				
4¼	1.76	1.79	1.81	1.83			
4½	2.13	2.17	2.21	2.23	2.24		
4¾	2.54	2.60	2.65	2.68	2.71	2.72	
5	2.99	3.08	3.15	3.20	3.23	3.25	3.26
5¼	3.50	3.61	3.70	3.77	3.81	3.85	3.87
5½	4.06	4.20	4.31	4.40	4.47	4.51	4.55
5¾	4.67	4.84	4.99	5.10	5.19	5.25	5.30
6	5.33	5.55	5.72	5.86	5.98	6.06	6.13
6¼	6.05	6.31	6.52	6.70	6.84	6.95	7.04
6½	6.83	7.13	7.39	7.60	7.78	7.92	8.03
6¾	7.66	8.02	8.32	8.58	8.79	8.97	9.11
7	8.56	8.97	9.33	9.63	9.89	10.10	10.28
7¼	9.52	9.99	10.41	10.76	11.07	11.32	11.54
7½	10.54	11.08	11.56	11.97	12.33	12.63	12.89
7¾	11.62	12.24	12.79	13.27	13.68	14.04	14.34
8	12.78	13.48	14.09	14.64	15.12	15.53	15.89
8¼	14.00	14.78	15.48	16.10	16.64	17.12	17.54
8½	15.28	16.16	16.95	17.65	18.27	18.81	19.29
8¾	16.64	17.62	18.50	19.28	19.98	20.60	21.15
9	18.08	19.16	20.13	21.01	21.79	22.49	23.11
9¼	19.58	20.77	21.85	22.83	23.70	24.49	25.19
9½	21.16	22.47	23.66	24.74	25.71	26.59	27.38
9¾	22.81	24.25	25.56	26.75	27.83	28.80	29.68
10	24.54	26.11	27.54	28.85	30.04	31.12	32.10

Cylindrical Pillars of

Safe weight, in tons of 2,000 pounds, which they can support,
ing columns, in which the thickness of the iron is given in

Diameter of Pillar outside.	Solid.	⅜ Inch.	½ Inch.	⅝ Inch.	¾ Inch.	⅞ Inch.	1 Inch.	1⅛ Inch.
Inches.								
2	0.12	0.10	0.11					
2¼	0.18	0.14	0.16	0.17				
2½	0.26	0.19	0.22	0.24	0.25			
2¾	0.37	0.25	0.30	0.33	0.35	0.36		
3	0.50	0.32	0.38	0.43	0.46	0.48	0.49	
3¼	0.67	0.41	0.49	0.55	0.60	0.63	0.65	0.66
3½	0.87	0.50	0.61	0.69	0.75	0.80	0.83	0.85
3¾	1.11	0.61	0.74	0.85	0.93	0.99	1.04	1.07
4	1.40	0.73	0.90	1.03	1.14	1.22	1.28	1.33
4¼	1.74	0.86	1.07	1.23	1.37	1.47	1.55	1.62
4½	2.13	1.01	1.26	1.46	1.62	1.76	1.86	1.94
4¾	2.58	1.18	1.46	1.71	1.91	2.07	2.21	2.31
5	3.09	1.35	1.69	1.98	2.22	2.42	2.59	2.72
5¼	3.68	1.55	1.94	2.28	2.56	2.80	3.01	3.17
5½	4.34	1.76	2.21	2.60	2.94	3.22	3.46	3.67
5¾	5.08	1.99	2.50	2.95	3.34	3.68	3.96	4.21
6	5.91	2.23	2.81	3.33	3.78	4.17	4.50	4.79
6¼	6.83	2.49	3.15	3.73	4.25	4.70	5.09	5.43
6½	7.85	2.77	3.51	4.17	4.75	5.27	5.72	6.11
6¾	8.97	3.07	3.89	4.63	5.29	5.88	6.39	6.84
7	10.21	3.38	4.30	5.13	5.87	6.53	7.12	7.63
7¼	11.56	3.71	4.73	5.66	6.48	7.22	7.88	8.47
7½	13.04	4.07	5.19	6.21	7.13	7.96	8.70	9.36
7¾	14.65	4.44	5.68	6.80	7.82	8.74	9.57	10.31
8	16.40	4.84	6.19	7.43	8.55	9.57	10.49	11.32
8¼	18.29	5.25	6.73	8.08	9.32	10.44	11.46	12.38
8½	20.33	5.69	7.29	8.77	10.13	11.36	12.49	13.51
8¾	22.54	6.14	7.89	9.50	10.98	12.33	13.57	14.69
9	24.91	6.62	8.51	10.26	11.87	13.35	14.70	15.94
9¼	27.45	7.12	9.16	11.06	12.80	14.41	15.89	17.25
9½	30.18	7.64	9.84	11.89	13.78	15.53	17.14	18.62
9¾	33.10	8.19	10.56	12.76	14.80	16.70	18.45	20.05
10	36.21	8.75	11.30	13.67	15.87	17.92	19.81	21.56

Cast-iron **30** *feet long.*

if solid, as in the first column, or if hollow, as in the succeed- the respective headings.

Diameter of Pillar outside.	1¼ Inch.	1⅜ Inch.	1½ Inch.	1⅝ Inch.	1¾ Inch.	1⅞ Inch.	2 Inch.
Inches.							
2							
2¼							
2½							
2¾							
3							
3¼							
3½	0.86						
3¾	1.09	1.10					
4	1.36	1.38	1.39				
4¼	1.66	1.69	1.71	1.73			
4½	2.01	2.05	2.08	2.10	2.12		
4¾	2.39	2.46	2.50	2.53	2.55	2.57	
5	2.83	2.91	2.97	3.02	3.05	3.07	3.08
5¼	3.31	3.41	3.49	3.56	3.60	3.63	3.65
5½	3.83	3.97	4.07	4.15	4.22	4.26	4.29
5¾	4.41	4.57	4.71	4.81	4.89	4.96	5.00
6	5.03	5.23	5.40	5.53	5.64	5.72	5.78
6¼	5.71	5.95	6.16	6.32	6.46	6.56	6.64
6½	6.45	6.73	6.97	7.18	7.34	7.48	7.58
6¾	7.23	7.57	7.86	8.10	8.30	8.47	8.60
7	8.08	8.47	8.81	9.09	9.34	9.54	9.70
7¼	8.98	9.43	9.82	10.16	10.45	10.69	10.89
7½	9.95	10.46	10.91	11.30	11.64	11.93	12.17
7¾	10.97	11.56	12.07	12.52	12.91	13.25	13.54
8	12.06	12.72	13.31	13.82	14.27	14.66	15.00
8¼	13.21	13.95	14.61	15.20	15.71	16.16	16.55
8½	14.43	15.26	16.00	16.66	17.24	17.76	18.21
8¾	15.71	16.63	17.46	18.20	18.86	19.45	19.96
9	17.06	18.08	19.00	19.83	20.57	21.23	21.82
9¼	18.48	19.61	20.63	21.55	22.38	23.12	23.78
9½	19.97	21.21	22.33	23.35	24.27	25.10	25.84
9¾	21.53	22.89	24.12	25.25	26.27	27.19	28.02
10	23.17	24.65	26.00	27.24	28.36	29.38	30.30